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*The Testimonial to Mr. Wesley.*

I have received from Professor Turner the subjoined letter which I think it well should be published in the *Monthly Notices*, as it is self-explanatory, and will, I am certain, be read with interest by the Fellows. The response to the movement so thoughtfully inaugurated by our past President has been most gratifying, and affords ample testimony of the high esteem and regard in which Mr. Wesley is held by those with whom he has been so long and so honourably associated.

I also subjoin a letter addressed to me by Mr. Wesley, which I have great pleasure in publishing.

I feel sure also that I shall be acting in full accordance with the wishes of all subscribers to the testimonial if I tender to Professor Turner hearty congratulations at the success which has attended his action, and thanks for the great personal trouble which he has taken in carrying the matter through.

W. H. MAW.

Professor Turner's letter is as follows :

*To the President of the Royal Astronomical Society.*

University Observatory, Oxford.

DEAR MR. PRESIDENT,—You will remember that at the beginning of the year I invited a friendly recognition of the thirty years' service which our Assistant Secretary, Mr. W. H. Wesley, had just completed. The suggestion was cordially responded to, and I handed to him at the annual meeting a cheque for £140 on account ; but the list was kept open for the benefit

of any Fellows who might through oversight have not yet availed themselves of the opportunity of joining.

As I am now starting for Egypt to observe the Eclipse, it seems better to close the list definitely. I beg to hand to you an account of the sums subscribed, from which you will see that the total amount received from the 168 subscribers was £155 9*s.* 7*d.* The expenses of postage, printing, &c., amounted to £3 14*s.* 7*d.*, leaving a balance of £151 15*s.*, so that I am sending Mr. Wesley to-day a further cheque for £11 15*s.*

It has been suggested that a list of the subscribers (*names* only, and not *amounts*) should be handed to Mr. Wesley, but that beyond this it is not desirable to publish any details. I have accordingly handed to Mr. Wesley such a list of names together with portions from many cordial letters received—taking particular care to cut out from the letters any suggestion as to the actual amount subscribed. But should you consider it advisable to publish any details, I have placed the material in your hands.

I may add that Mr. and Mrs. Wesley have loyally attended to the suggestion in the circular as regards a holiday. They have been for three weeks in Switzerland and thoroughly enjoyed it—indeed, Mr. Wesley is good enough to call it "the finest holiday of their lives." I feel sure their many friends will be glad to hear this.

Believe me, dear Mr. President,
Yours very truly,
H. H. TURNER.

1905 *July* 26.

Burlington House, London, W.

DEAR MR. MAW,—I should be very glad if I may be allowed the opportunity of thanking the Fellows of the Royal Astronomical Society for the Testimonial to which they have so freely subscribed.

Mrs. Wesley and I are especially gratified at the generous and appreciative words contained in the extracts from letters which accompanied the subscriptions. I shall always treasure these extracts as a testimony of the good will and kindly feeling of those with whom my official position has brought me in contact.

I should like also again to thank Professor Turner for all his trouble and thoughtfulness.

Yours very sincerely,
W. H. WESLEY.

1905 *August* 14.

### *Latitude Stations in the Southern Hemisphere.*

(*Communicated by the Secretaries.*)

In a circular issued by the Central International Geodetic Bureau of date 1905 September, Dr. Albrecht reports progress in the matter of the establishment of latitude stations in the southern hemisphere (cf. *Monthly Notices*, lxiii. pp. 294, 394). The Central Bureau have now arranged for the actual commencement of southern latitude work in 1906 January at two stations on the parallel $-31^\circ\ 55'$: one of these is at Bayswater, in West Australia, in longitude $-115^\circ\ 54'{\cdot}5$, and the other at Oncativo, in Argentina, in longitude $63^\circ\ 42'$. Dr. Curt Hessen and Dr. Luigi Carnera have respectively been appointed to the charge of the work.

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### *The Next International Scheme. A Suggestion.*

By W. Ernest Cooke.

The great photographic Durchmusterung is approaching completion. At a number of observatories this special work will soon be finished, and the officers in charge will be looking for the most useful direction towards which they may turn their energies. Now is the time, therefore, to consider the advisability of continuing the practice of international co-operation, and to discuss suggestions for the next concerted action.

I wish to put forward a plea for united effort in meridian work. Our present haphazard method leads to disappointing results, altogether disproportionate to the skill and labour expended. If the millions of observations that have been taken in the past had been properly co-ordinated we ought to be able to obtain good star positions in abundance in any portion of the sky. This is certainly not the case at present. It is a matter of every-day occurrence that an astronomer desires a number of reference points in some particular field, and as a general rule is obliged to use approximate positions first, and re-observe his reference stars with the transit circle at the next convenient opportunity. If he attempt to obtain the positions from existing catalogues he will probably find that most of his star positions have been determined *once* somewhere or other, but he will be very fortunate if he obtains sufficiently accurate information to bring the positions up to date. It is, moreover, disappointing to the transit observer to feel that he is putting an immense amount of work into a catalogue the greater part of which will never be used.

I believe both these difficulties will be overcome by the following plan:

Let three catalogues be prepared as soon as possible, and astronomers be requested to confine their meridian or other

exact work in future mainly to the stars in one or other of these catalogues.

A. Bright stars. This does not form part of the proposed scheme, but, of course, the regular observation of the principal stars must be continued.

B. Fundamental stars for the general scheme. As a matter of detail I suggest that these be selected of about the sixth magnitude, and in every region of the sky.

C. Main catalogue, comprising, say, three stars to every square degree, and, of course, including the whole of B. This would make a total of over 120,000 stars.

Leaving A to take care of itself, astronomers would be asked to take up *either* B or C. In observing the B stars accuracy would be the main consideration, and no amount of time or trouble should be begrudged for this end. They might also be observed by totally different methods, such as that of the almucantar. In fact, all the resources of exact astronomy should be brought to bear upon the compilation of this catalogue. The positions thus obtained would be adopted as the foundation of the C list. Observers taking up this main catalogue would work through one or two degrees of declination at a time, including at least six of the fundamental stars in each evening's work, and obtaining from them the clock error, and zenith, or equator point. They need not be troubled greatly with anomalies in refraction, reflection, instrumental errors, &c., as their computations would be mainly differential.

In working out the general scheme each observatory might gradually advance zone by zone from the zenith to the pole, arranging for suitable overlaps ; or might take charge of a certain section of the sky and repeat every ten years ; or there might be a combination of both methods. But the main point is that the position of each star would be determined with fair accuracy during each decade ; and by the time we are ready to repeat the photographic work now occupying our attention our standard stars will be ready waiting for us, their positions determined with great accuracy, and their proper motions known with some amount of precision. By that time also the international catalogue will be universally adopted, and all haphazard meridian work will have ceased.

The main idea of this scheme is the preparation of two catalogues, and the promise of some of the leading astronomers to make one or the other the basis of their future working lists. A considerable proportion of the labour of compiling C has been already done in selecting the standard stars for the photographic Durchmusterung. There would be some distinct advantages in utilising these same stars ; but, whatever method be adopted, the list should be prepared, sanctioned by leading astronomers, and printed. The preparation of B would require great care, but would probably be undertaken by those who have already performed similar work, such as Professor Auwers.

This is all that is really necessary, for when the lists are once sanctioned observers who have the opportunity can start work immediately, knowing that *not one single observation will thenceforward be wasted*, and that the sooner they commence the more valuable will their results eventually become.

Of course an international committee ought, if possible, to be appointed, to meet occasionally and see that there are no gaps; and if they have opportunities of obtaining funds for printing so much the better; but this, though desirable, is not essential. Let us have the scheme discussed, and, if considered advisable, have the catalogues prepared forthwith.

*Perth Observatory, Western Australia:*
1905 *July* 4.

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## *On the Secular Accelerations of the Moon's Longitude and Node.*

By P. H. Cowell.

In this paper I determine the secular accelerations of the Moon's longitude and node from the solar eclipses of the years −1062, −762, −647, −430, and +197.

The historical references are as follows:—

1. Inscription at Babylon:

"On the 26th day of the month Sivan, in the 7th year, the day was turned into night, and fire in the midst of heaven."

This inscription was communicated to me by Mr. L. W. King, of the Department of Egyptian and Assyrian Antiquities, British Museum, the translator, early in September. I may add that a few days previously I had shown to Professor Newcomb, in MS., the corrections that I had deduced from the other four eclipses mentioned in this paper. It turned out that this eclipse supported the corrections deduced from the other four.

2. Inscription at Nineveh:

"In the month Sivan the Sun underwent an eclipse."

3. Archilochus, 74:

Ζεὺς πατὴρ Ὀλυμπίων
ἐκ μεσημβρίης ἔθηκε νύκτ' ἀποκρύψας φάος
ἠλίου λάμποντος.

4. Thucydides, II. 28:

Τοῦ δ' αὐτοῦ θέρους νουμηνίᾳ κατὰ σελήνην, ὥσπερ καὶ μόνον δοκεῖ εἶναι γίγνεσθαι δυνατόν, ὁ ἥλιος ἐξέλιπε μετὰ μεσημβρίαν καὶ πάλιν ἀνεπληρώθη, γενόμενος μηνοειδὴς καὶ ἀστέρων τινῶν ἐκφανέντων.

5. Tertullian ad Scapulam, c. 3:

"Nam et sol ille in conventu Uticensi, extincto pæne lumine, adeo portentum fuit, ut non potuerit ex ordinario deliquio hoc pati, positus in suo hypsomate et domicilio. Habetis astrologos."

The method is as follows :—

Let T be an approximate time reckoned in Julian centuries from 1800 January 0·0 G.M.T.

Let V, U, $p$ be the Moon's tabular longitude and latitude and parallax ; let $V+\Delta V$, $U+\Delta U$ be the Moon's true longitude and latitude.

Let $V'$, $p'$ be the Sun's tabular longitude and parallax.

Let $v'$, $u'$ be the parallax in longitude and latitude calculated for the Sun's place with the negative parallax $p'-p$.

Let $T+t$ be the time of apparent conjunction in longitude.

For convenience $t$ is measured in units of one-millionth part of a Julian century, or about fifty-three minutes.

Thus by definition of $t$

$$V-V'-v'+t\frac{d}{dt}(V-V'-v')+\Delta V=0$$

If the place chosen for calculation is on the central line, then the apparent latitudes must be equal ; or

$$U-u'+t\frac{d}{dt}(U-u')+\Delta U=0$$

Eliminate $t$ ; put

$$\frac{d}{dt}(U-u')=k\frac{d}{dt}(V-V'-v')$$

then

$$\Delta U-k\Delta V=k(V-V'-v')-(U-u')$$

This is the equation of condition for centrality. $k$ is usually a small fraction, but its maximum value is $\frac{1}{3}$. It will be observed that $\Delta V$ has $k$ as a factor. The central line runs eastward ; an alteration of V alters the time at which the Moon is interposed between the Earth and the Sun, and therefore the face of the Earth turned to the Sun is altered by diurnal rotation. This course alone shifts every point on the central line due east or west ; and the two positions of the central line are not very widely separated, except that one line overlaps the other at its west end and the other at its east.

If we assume that the parts of $\Delta V$, $\Delta U$ that arise from corrections to the secular accelerations outweigh in importance all other corrections required by the tables (this is obviously the case if the tabular secular accelerations are one second in error), we may put

$$\Delta U=\pm 0\cdot 0895T^2 s_F \qquad \Delta V=T^2 s_L$$

where $s_F$, $s_L$ are the corrections required by the secular accelerations of the argument of latitude and mean longitude.

The Hansen-Newcomb tables of the Moon now in use in the *Nautical Almanac* are based upon the following formulæ :

$$g = 110^\circ\ 19'\ 32''{\cdot}50 + 171791\ 5807''{\cdot}98T + 45''{\cdot}675T^2 + 0''{\cdot}050073T^3$$
$$\omega = 192\ \ 7\ 21{\cdot}91 + \ \ 2161\ 1522{\cdot}07T - 44{\cdot}323T^2 - 0{\cdot}043759T^3$$
$$-\Omega = 326\ 43\ 28{\cdot}85 + \ \ 696\ 2939{\cdot}61T - \ 8{\cdot}189T^2 - 0{\cdot}007159T^3$$

The Newcomb tables of the Sun now in use in the *Nautical Almanac* are based upon the formulæ

$$L' = 279^\circ\ 54'\ 28''{\cdot}75 + 12960\ 2765'{\cdot}95T + 1''{\cdot}089T^2$$
$$\pi' = 279\ 29\ 47{\cdot}26 + \ \ \ \ 6185{\cdot}80T + 1{\cdot}590T^2 + 0''{\cdot}012T^3$$

where I have transferred the epoch to 1800 Jan. 0·0 G.M.T.

The formulæ employed in the present calculations are

$$g = 110^\circ\ 19'\ 38'' + 171791\ 5794''T + 44''{\cdot}4T^2 + 0''{\cdot}050T^3$$
$$\omega = 192\ \ 7\ 25 + \ \ 2161\ 1516T - 40{\cdot}0T^2 - 0{\cdot}044T^3$$
$$-\Omega = 326\ 43\ 39 + \ \ 696\ 2921T - \ 3{\cdot}7T^2 - 0{\cdot}007T$$
$$L' = 279\ 54\ 29 + \ 12960\ 2766T + \ 1{\cdot}1T^2$$
$$\pi' = 279\ 29\ 47 + \ \ \ \ 6186T + \ 1{\cdot}6T^2 + 0{\cdot}012T^3$$

The solar elements L′, $\pi'$, and the cube terms of the lunar elements have been modified only to the extent of omitting a few insignificant figures. The other alterations are

$$\Delta g = + \ 5''{\cdot}50 - 13''{\cdot}98T - 1''{\cdot}275T^2$$
$$\Delta\omega = + \ 3{\cdot}09 - \ 6{\cdot}07T + 4{\cdot}323T^2$$
$$-\Delta\Omega = + 10{\cdot}15 - 18{\cdot}61T + 4{\cdot}489T^2$$

whence

$$\Delta L = -1''{\cdot}56 - \ 1''{\cdot}44T - 1''{\cdot}441T^2$$
$$\Delta\varpi = - \ 7{\cdot}06 + 12{\cdot}54T - 0{\cdot}166T^2$$
$$\Delta F = + 8{\cdot}59 - 20{\cdot}05T + 3{\cdot}048T^2$$

The constants and centennial motions are approximately those deduced by myself from modern observations. The secular accelerations of L and F are approximately those deduced in the present investigation, which has been rewritten with the corrections introduced. The secular term of the perigee is hardly altered from Hansen. I decided not to introduce into it an empirical correction of $+3''$ with a possible error of $\pm 7''$, which I deduced in *Monthly Notices*, lxv. p. 275, from the observations 1750–1901.

The mean motions employed are probably correct to within $5''$. An error of $5''$ in any mean motion can be approximately balanced by an alteration $0''{\cdot}3$ in the secular term

No correction for the position of the perigee is introduced into the equations of condition. If all the eclipses considered occurred at perigee, an error in the perigee could be balanced by an alteration of the mean longitude of one-ninth the amount. With the actual eclipses employed, the residuals could be diminished by a properly chosen correction to the perigee, but such a correction would not be entitled to any weight.

The secular acceleration of the mean sidereal motion employed in my tabular places is $+7''{\cdot}0$.

The inequalities of the Moon are calculated from the following formulæ :

$$
\begin{aligned}
V-L = {} & 22640'' \sin g \\
& + 4586 \sin(-g+2D) \\
& + 2370 \sin 2D \\
& + 769 \sin 2g \\
& + 669 \sin -g' \\
& + 412 \sin -2F \\
& + 212 \sin(-2g+2D) \\
& + 206 \sin(-g-g'+2D) \\
& + 192 \sin(g+2D) \\
& + 165 \sin(-g'+2D) \\
& + 148 \sin(g-g') \\
& + 125 \sin -D \\
& + 110 \sin(-g-g') \\
& + 55 \sin(-2F+2D) \\
& + 45 \sin(-g-2F) \\
& + 40 \sin(g-2F) \\
& + 38 \sin(-g+4D) \\
& + 36 \sin 3g \\
& + 31 \sin(-2g+4D) \\
& + 29 \sin(g-g'-2D) \\
& + 24 \sin(-g'-2D)
\end{aligned}
$$

$$
\begin{aligned}
U = {} & 18461'' \sin F \\
& + 1010 \sin(g+F) \\
& + 1000 \sin(g-F) \\
& + 624 \sin(-F+2D) \\
& + 199 \sin(-g+F+2D) \\
& + 167 \sin(-g-F+2D) \\
& + 117 \sin(F+2D) \\
& + 62 \sin(2g+F) \\
& + 33 \sin(g-F+2D) \\
& + 32 \sin(2g-F) \\
& + 30 \sin(-g'-F+2D) \\
& + 16 \sin(-2g-F+2D) \\
& + 15 \sin(g+F+2D) \\
& + 12 \sin(-g'+F-2D)
\end{aligned}
$$

$$p-p' = 3414'' + 187'' \cos g + 34'' \cos(-g+2D) + 28'' \cos 2D + 10'' \cos 2g$$

$$\frac{d}{dt}(V-V') = 1632'' + 227'' \cos g + 13'' \cos 2g - 5 \cos g'$$

$$\pm\frac{dU}{dt} = 163'' + 20'' \cos g + 2'' \cos 2g$$

The last two expressions have been reduced by putting $D = 0$,

$2F = 0$ in the accurate expressions. For the Sun the formula used is

$$V' - L' = e_1' \sin g' + e_2' \sin 2g'$$

where

$$e_1' = 6927''\cdot2 - 17''\cdot14T - 0''\cdot052T^2$$
$$e_2' = \quad 72\cdot7 - \quad 0\cdot36T$$

The corrections for parallax are calculated by the formulæ

| | |
|---|---|
| $= (p-p') \sin\lambda \sin\varepsilon \cos V'$ | $\frac{dv'}{dt} =$ |
| $+(p-p') \cos\lambda \cos^2\frac{\varepsilon}{2} \sin(h-V')$ | $0\cdot2295 \times (p-p') \cos\lambda \cos^2\frac{\varepsilon}{2} \cos(h-V')$ |
| $-(p-p') \cos\lambda \sin^2\frac{\varepsilon}{2} \sin(h+V')$ | $-0\cdot2307 \times (p-p') \cos\lambda \sin^2\frac{\varepsilon}{2} \cos(h+V')$ |
| $= (p-p') \sin\lambda \cos\varepsilon$ | $\frac{du'}{dt} =$ |
| $-(p-p') \cos\lambda \sin\varepsilon \sin h$ | $-0\cdot2301 \times (p-p') \cos\lambda \sin\varepsilon \cos h$ |

where $\varepsilon$ is the obliquity of the ecliptic

$$\varepsilon = 23^\circ\ 27'\ 55''\cdot1 - 46''\cdot83T$$
$$\sin\varepsilon = 0\cdot4023\ 5 - 0\cdot0002\ 1(T+20)$$
$$\cos\varepsilon = 0\cdot9154\ 9 + 0\cdot0000\ 9(T+20)$$

and $\lambda$ is the latitude of the place of calculation and $h$ the local sidereal time.

Owing to their rapid curvature the parallactic corrections for $T+t$ can only be calculated by the formula given, if the correction $t$ is small.

The numerical work is given below. The calculations are extended to the eclipse of $-1069$ June 20, in order to show that the eclipse of this date was not total at Babylon. I should add that Mr. King would have much preferred a date in June being assigned to his eclipse instead of a date in July, owing to the reference to the month Sivan.

| Ref. No. | T. | Place. | Authority. | Lat. N. | Long. N. |
|---|---|---|---|---|---|
| 0 | $-28\cdot6850167$ | Babylon | ... | $+32^\circ\ 26'$ | $+44^\circ\ 13'$ |
| 1 | $-28\cdot6138889$ | „ | Inscription | $+32\ 26$ | $+44\ 13$ |
| 2 | $-25\cdot6151436$ | Nineveh | „ | $+36\ 24$ | $+43\ 0$ |
| 3 | $-24\cdot4670532$ | Thasos | Archilochus | $+40\ 40$ | $+24\ 40$ |
| 4 | $-22\cdot2937936$ | Athens | Thucydides | $+37\ 56$ | $+23\ 38$ |
| 5 | $-16\cdot0254612$ | Utica | Tertullian | $+37\ 10$ | $+10\ 0$ |

| Ref. No. | Local Mean Time Corresponding to T. d h m | $T^2$. | $T^3$. | $0{\cdot}0895\ T^2$. | $g$. |
|---|---|---|---|---|---|
| 0 | −1069 June 19 28 18·5 | 822·83 | −23603 | 74 | 303° 41′ 32″ |
| 1 | −1062 July 30 19 56·3 | 818·75 | −23428 | 73 | 45 44 51 |
| 2 | − 762 June 14 23 59·2 | 656·14 | −16807 | 59 | 41 35 15 |
| 3 | − 647 April 5 22 48·5 | 598·64 | −14647 | 54 | 348 18 21 |
| 4 | − 430 Aug. 3 6 6·3 | 497·01 | −11080 | 45 | 264 2 38 |
| 5 | + 197 June 3 1 22·7 | 256·82 | − 4116 | 23 | 262 4 33 |

| Ref. No. | $\omega$. | $-\Omega$. | L′. | $\pi'$. | L. |
|---|---|---|---|---|---|
| 0 | 61° 24′ 33″ | 284° 57′ 15″ | 77° 31′ 7″ | 230° 29′ 35″ | 80° 8′ 50″ |
| 1 | 128 26 48 | 62 31 46 | 118 10 23 | 230 36 50 | 111 39 53 |
| 2 | 132 14 13 | 102 41 28 | 75 15 29 | 235 43 0 | 71 8 0 |
| 3 | 185 3 51 | 163 19 9 | 7 22 37 | 237 40 16 | 10 3 3 |
| 4 | 272 39 36 | 46 48 55 | 126 21 40 | 241 22 20 | 129 53 19 |
| 5 | 105 17 21 | 290 54 38 | 71 4 14 | 252 3 35 | 76 27 16 |

| Ref. No. | V−L. | V′−L′. | V−V′. | U. | $\frac{d}{dt}(V-V')$. | $\frac{dU}{dt}$ | $p-p'$. |
|---|---|---|---|---|---|---|---|
| 0 | −14907″ | −3285″ | −2159″ | + 231″ | +1757″ | +173″ | 3558″ |
| 1 | +13676 | −6758 | −2996 | + 718 | +1792 | −177 | 3589 |
| 2 | +12442 | −2399 | − 8 | + 875 | +1809 | −178 | 3605 |
| 3 | − 4176 | +5548 | − 98 | +2375 | +1869 | −185 | 3667 |
| 4 | −17107 | −6538 | +2130 | +2577 | +1597 | −159 | 3405 |
| 5 | −17951 | + 121 | +1310 | + 776 | +1593 | +158 | 3394 |

| Ref. No. | $h$=Local Sid. Time. | $v'$. | $u'$. |
|---|---|---|---|
| 0 | 37° 9′ | +179−1827−117=−1765″ | +1745− 733=+1012′ |
| 1 | 57 14 | −345−2488− 15=−2848 | +1761−1029=+ 732 |
| 2 | 75 3 | +229+ 23− 62=+ 190 | +1957−1131=+ 826 |
| 3 | 349 31 | +952− 885+ 3=+ 70 | +2187+ 204=+2391 |
| 4 | 217 57 | −478+2567+ 34=+2123 | +1916+ 665=+2581 |
| 5 | 91 45 | +267+ 914− 34=+1147 | +1877−1086=+ 791 |

| Ref. No. | $\frac{dv'}{dt}$. | $\frac{du'}{dt}$. | $\frac{d}{dt}(V-V'-v')$ =denom. of $k$. | $\frac{d}{dt}(U-u')$ =num. of $k$. | $k$ |
|---|---|---|---|---|---|
| 0 | +510+12=+522″ | −222″ | +1235″ | +395″ | +·320 |
| 1 | +342+30=+372 | −153 | +1420 | − 24 | −·017 |
| 2 | +638+24=+662 | − 69 | +1147 | −109 | −·095 |
| 3 | +576−27=+549 | −254 | +1320 | + 69 | +·052 |
| 4 | − 35−25=− 60 | +196 | +1537 | −355 | −·231 |
| 5 | +557+25=+582 | + 8 | +1011 | +150 | +·148 |

| Ref. No. | $-kT^2$. | $V-V'-v'$. | $t$. | $k(V-V'-v')-(U-u')$. |
|---|---|---|---|---|
| 0 | −263 | −394 | +0·3 | +655″ |
| 1 | + 13 | −148 | +0·1 | + 17 |
| 2 | + 62 | −198 | +0·2 | − 30 |
| 3 | − 31 | −168 | +0·1 | + 8 |
| 4 | +115 | + 7 | 0·0 | + 2 |
| 5 | − 38 | +163 | −0·2 | + 39 |

The large value in the first line of the last column shows that about one-third of the Sun was visible at Babylon at the maximum phase of the eclipse of −1069 June 20.

The equations of condition resulting from the other five eclipses are :

$$\begin{aligned}
-73\,s_F + 13\,s_L &= +17 \\
-59\,s_F + 62\,s_L &= -30 \\
-54\,s_F - 31\,s_L &= +8 \\
-45\,s_F + 115\,s_L &= +2 \\
+23\,s_F - 38\,s_L &= +39
\end{aligned}$$

In some cases the right-hand sides are less than the difference of semi-diameters. A least-squares solution gives $s_L = -0''{\cdot}18$, $s_F = -0''{\cdot}05$ ; but these quantities are less than the probable errors.

The eclipse of Agathocles −309 Aug. 15 is central about fifty miles north of Syracuse. The figures are not reproduced here.

The equation of condition for the eclipse of −1062 shows that, with Hansen's position of the node, totality, even in the neighbourhood of Babylon, is impossible without a large increase of the secular acceleration.

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*On the Value of Ancient Solar Eclipses.* By P. H. Cowell.

In *Ast. Nach.*, No. 3682, Professor Newcomb argues against the corrections to the three lunar elements, viz. the mean longitude and the longitude of perigee and node, based by Oppolzer and Ginzel on ancient solar eclipses. These corrections, as Professor Newcomb points out, are incompatible with modern observations and with theory, and I, like Professor Newcomb, believe them to be erroneous.

In the opening paragraphs of the paper referred to, Professor Newcomb lays down that "no attempt should be made to determine the motion either of the perigee or node from ancient eclipses" on the ground that their centennial motions have been settled by the accordance of modern observation with theory to within limits of error that would have no "appreciable effect on the paths of ancient eclipses." Professor Newcomb, however, ignores the possibility of errors in the secular variations. Now

these secular variations cannot be determined to within 5″ by modern observations, and the theory is certainly not above suspicion. No theoretical values have to my knowledge been published since Hansen's, who, in the case of the mean longitude, gave the erroneous value of 12″.

Now any error in the assumed value of $g$, the mean anomaly, introduces into the Moon's tabular longitude an error $\frac{1}{9}\cos g$ times the same amount. Probably, therefore, the secular term in the position of the perigee cannot be determined from ancient eclipses with an accuracy much superior to that resulting from modern observations.

Hansen's secular term in the longitude of the node, however, I believe to be erroneous by over 4″, corresponding to an error of nearly one degree in the earliest eclipses. Modern observations cannot criticise this correction, and the objection to it is wholly theoretical.

Later on in the paper referred to, Professor Newcomb raises the question, "To what extent, if at all, are we justified in determining the secular acceleration of the Moon from the supposed solar eclipses recorded by ancient historians?" When we examine Professor Newcomb's distrust of ancient solar eclipses, we find it is mainly, if not entirely, due to the fact that the eclipse of Xerxes, in the spring of the year of Salamis, cannot be identified at all, and that in the eclipse of Thales (−584) modern values of the secular acceleration make the central line end to the west of Asia Minor. Hence Professor Newcomb concludes that ancient eclipses, purporting to be total, cannot safely be assumed to have been so. I submit that the true inference is that ancient eclipses, when described by Herodotus or other historians born, as in the case of the eclipse of Thales, a hundred years after the event described, may be rejected. Herodotus's reputation for accuracy is, I believe, confined to the description of events and customs that he himself saw. "Apud Herodotum," says Cicero, "sunt innumerabiles fabulæ." But the inaccuracies of Herodotus are no ground for rejecting an eclipse described by Thucydides, who expressly tells us that he noted down events at the time that they occurred. Again, in the case of inscriptions at Babylon and Nineveh, it seems probable that total eclipses alone would be recorded. Partial eclipses are not particularly rare or impressive phenomena, and in the case of the eclipse of −1062, the words "fire in the midst of heaven" seem conclusive. The poet Archilochus, too, may be credited with having described what he saw. Again, as Tertullian considered the eclipse he refers to supernatural, it may be inferred that he would have supposed its theological significance reduced almost to zero if it had fallen far short of totality.

The evidence that I have made use of is therefore, I believe, in every case the evidence of eye-witnesses; but the *a priori* arguments I consider to be completely overshadowed by the *a posteriori* ones. For I have found that the same two correc-

tions satisfy the equations of condition for five eclipses, and that one of these corrections is further supported by Mr. Nevill's amendment (*Monthly Notices*, vol. xxxix.) to Professor Newcomb's discussion of ancient lunar eclipses. If the eclipses were total, the numerical values of my corrections are correct ; if the eclipses were partial, then the amazing accident must have occurred that all five are such that they can be rendered tabularly total by the same alterations of the tables.

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*The Annular Eclipse, 1905 March 6, observed in South Australia.*
Communicated by Sir Charles Todd, K.C.M.G., F.R.S.

The conditions for observing the recent partial eclipse of the Sun in South Australia were extremely favourable. As shown in the *Nautical Almanac*, the central line entered the Australian continent at the head of the Great Bight, and emerged on the East Coast about lat. 22° 50′, passing therefore through our sparsely settled interior. In Adelaide the magnitude of the eclipse was 0·827 ; at Cradock (lat. 32° 5′) the observer says the annulus was almost discernible at mid-phase. I was unfortunately away in Melbourne, but Mr. Griffiths made very careful observations and furnishes the following notes.

"The eclipse was observed under very good atmospheric conditions. The first contact was noted at $1^h\ 51^m\ 52^s{\cdot}9$ standard time, or $1^h\ 36^m\ 13^s{\cdot}2$ Adelaide mean time. This is probably within a second or two of the real time, as I was looking at the exact spot : the limb was beautifully defined, and the merest indentation was observed. There were two large groups of spots on the Sun visible to the naked eye, one on the western side and the other in the eastern hemisphere. The Moon reached the western group at $2^h\ 14^m\ 37^s{\cdot}9$, or $1^h\ 58^m\ 58^s{\cdot}2$ A.M.T., and finally covered it at $2^h\ 23^m\ 25^s{\cdot}8$, or $2^h\ 7^m\ 46^s{\cdot}1$ A.M.T. ; the second or larger group was reached at $2^h\ 58^m\ 5^s{\cdot}4$ ($2^h\ 42^m\ 25^s{\cdot}7$ A.M.T.), and finally covered at $3^h\ 9^m\ 43^s{\cdot}4$ ($2^h\ 54^m\ 3^s{\cdot}7$ A.M.T.) The definition was at times perfect, and the most careful scrutiny of the spots as they passed behind the Moon failed to reveal any distortion or change in their appearance : the colour of their umbræ seemed to be decidedly lighter in tone than the black Moon. The final contact was noted at $4^h\ 54^m\ 26^s{\cdot}1$, or $4^h\ 38^m\ 46^s{\cdot}4$ A.M.T., and was very exact, the limb being steady.'

Taking the time of final contact, Captain Lee, the Superintendent of Prince Alfred Sailors' Home, Port Adelaide, made the longitude of the Observatory $9^h\ 14^m\ 15^s{\cdot}3$, the adopted longitude from a number of observations and comparisons with Melbourne and Sydney Observatories being $9^h\ 14^m\ 20^s{\cdot}3$, an excellent result from a single observation.

The following temperature observations were made at the Observatory.

| Standard Time. | | Shade. | | Relative Humidity. | Solar. | |
|---|---|---|---|---|---|---|
| | | D.B. | W.B. | | Lampblack Bulb in Vacuo. | Lampblack Bulb not in Vacuo. |
| h m s | h m | | | % | | |
| (1 44 20·3 A.M.T.) | 2 0 | 69·5 | 58·0 | 48 | 126·7 | 103·8 |
| | 10 | 71·1 | 58·6 | 46 | 126·8 | 105·5 |
| | 20 | 69·7 | 58·2 | 48 | 124·8 | 104·3 |
| | 30 | 69·5 | 58·6 | 50 | 118·8 | 97·5 |
| | 40 | 68·2 | 57·3 | 49 | 109·0 | 91·0 |
| | 50 | 68·7 | 58·0 | 51 | 102·0 | 89·1 |
| | 3 0 | 67·3 | 57·2 | 52 | 95·6 | 85·2 |
| | 10 | 66·2 | 56·7 | 54 | 88·0 | 78·5 |
| | 20 | 66·0 | 57·1 | 56 | 81·1 | 75·3 |
| | 30 | 65·2 | 57·0 | 58 | 76·8 | 73·0 |
| | 40 | 64·5 | 56·8 | 60 | 76·5 | 72·0 |
| | 50 | 64·9 | 57·2 | 60 | 80·4 | 75·7 |
| | 4 0 | 65·3 | 57·0 | 58 | 86·5 | 79·0 |
| | 10 | 66·0 | 57·1 | 56 | 92·5 | 83·0 |
| | 20 | 66·8 | 57·5 | 55 | 98·2 | 84·5 |
| | 30 | 67·0 | 57·8 | 55 | 102·5 | 90·0 |
| | 40 | 67·0 | 58·0 | 56 | 105·3 | 92·0 |
| | 50 | 67·0 | 58·0 | 56 | 106·2 | 92·3 |
| | 5 0 | 67·1 | 57·8 | 55 | 105·4 | ... |

Similar observations made by both private and official observers throughout the State give very similar differences to the above.

My friend Mr. A. W. Dobbie, who is a member of our local Astronomical Society and of the New South Wales branch of the B.A.A., and is an enthusiastic amateur astronomer, took a series of very interesting photographs, using an 18-inch silvered glass reflector, stopped down to $4\frac{1}{2}$ inches, copies of which (nine in all) I enclose. The first was taken at $1^h\ 58^m\ 5^s$ standard time, or $1^h\ 42^m\ 25^s$ A.M.T., and the last at $4^h\ 54^m\ 3^s$ ($4^h\ 38^m\ 23^s$ A.M.T.) or 23 seconds before final contact. The central phase, which occurred at $3^h\ 30^m$ standard time, is nearly shown by No. 5, taken at $3^h\ 27^m\ 37^s$. I might add that these are Mr. Dobbie's first attempts to photograph the Sun, and, further, that he ground the mirror, silvered it, and mounted it himself.

The decrease in the actinic power of the light during the eclipse was noted both here and at other places by exposing sensitised paper for definite periods as the eclipse progressed, and a measure of the decrease was obtained by the Rev. N. H. Louwyck, of Georgetown, by means of a Wynn Infallible Print Meter—this showed that with 16 as the value before the eclipse it decreased to between 5 and 6 (or $\frac{1}{3}$) at the middle phase.

*The Observatory, Adelaide:*
1905 *June* 8.

*Observations of Vesta made at the Natal Observatory, Durban.*
Communicated by E. Nevill.

The following observations were made by Mr. Rendell by means of a cross-bar micrometer with the equatorial refractor, aperture 8 inches, focal length 10 feet. Magnifying power 50.

| Date. 1905. | Greenwich Mean Time. | Apparent Difference. Vesta minus Star. R.A. | N.P.D. | Vesta's Approx. Hour-Angle. | No of Comparisons. | Comparison Star. |
|---|---|---|---|---|---|---|
| | h m s | m s | ″ | h m | | |
| May 23 | 3 54 27 | +1 30·64 | −8 11·3 | 2 3 E. | 7 | *a* |
| ,, | 5 38 53 | +1 32·12 | −7 57·8 | 0 18 E. | 4 | *a* |
| ,, | 6 32 2 | +1 32·64 | −7 29·3 | 0 35 W. | 4 | *a* |
| 24 | 6 47 21 | +1 52·26 | −0 41·3 | 0 54 W. | 7 | *a* |
| 25 | 3 54 55 | +2 11·01 | +5 20·9 | 1 55 E. | 6 | *a* |
| July 4 | 6 57 47 | +3 18·25 | −3 53·2 | 3 13 W. | 2 | *b* |
| 13 | 6 51 55 | +4 39·32 | +1 33·7 | 3 32 W. | 5 | *c* |

*Comparison Stars.*

| | | R.A. | N.P.D. | |
|---|---|---|---|---|
| | | h m s | ° ′ ″ | |
| *a*. | Lalande 22743 (Paris 14796) | 12 0 47·61 | 79 38 27·2 | (1875·0) |
| *b*. | ,, 23608 ( ,, 15505) | 12 31 42·27 | 86 1 45·3 | ,, |
| *c*. | ,, 23851 ( ,, 15726) | 12 41 17·62 | 87 37 51·3 | ,, |

*Notes.*

The observations have not been corrected for refraction or parallax.

May 23. The following observations were obtained with the 3-inch transit instrument:—

R.A. of Star *a* = 12 2 21·02
R.A. of Vesta = 12 3 53·07
} Diff. = $1^m\ 32^s{\cdot}05$ (G.M.T. = $5^h\ 57^m\ 10^s$)

July 4. Cloudy, observation doubtful.

*Natal Observatory, Durban:*
1905 *August* 31.

*The Magnitude of η Argûs*, 1905. By R. T. A. Innes.

The two comparison stars used are the same as on former occasions (*Monthly Notices*, lix. p. 570), viz. C. G. A. Cluster Catalogue, No. 121, mag. 8·0, colour on Chandler's scale 8, and Gilliss 1332, mag. 7·6, colour 4. The telescope used, a 4-inch refractor, belongs to Mr. R. N. Kotze.

| | | | | | |
|---|---|---|---|---|---|
| 1905 May | 20 | mag. = | 7·8 | | |
| „ | 25 | „ | 7·6 | | |
| June | 3 | „ | 7·7 | colour | 7 |
| „ | 24 | „ | 7·55 | „ | 8 |
| „ | 25 | „ | 7·7 | | |
| 1905·5 | | „ | 7·67 | „ | $7\frac{1}{2}$ |

The change, if any, since 1896 is quite insignificant.

*Johannesburg:* 1905 *June* 27.

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*Ephemeris for Physical Observations of the Moon for* 1906. By A. C. D. Crommelin.

| Greenwich Midnight. 1906. | Selenographical Colong. of the Sun. | Selenographical Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Geocentric Libration. Sel. Lat. of the Earth. | Physical Libration. Long. | Physical Libration. Lat. | C. |
|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° |
| Jan. 1 | 349·14 | +1·04 | +4·13 | +4·50 | +·003 | +·025 | 335·44 |
| 2 | 1·30 | +1·02 | +2·93 | +5·44 | ·000 | | 336·55 |
| 3 | 13·46 | +1·00 | +1·65 | +6·14 | −·002 | | 338·59 |
| 4 | 25·60 | +0·98 | +0·35 | +6·57 | −·003 | | 341·52 |
| 5 | 37·75 | +0·96 | −0·89 | +6·72 | −·005 | | 345·23 |
| 6 | 49·89 | +0·93 | −2·01 | +6·58 | −·008 | | 349·66 |
| 7 | 62·02 | +0·91 | −2·98 | +6·15 | −·010 | | 354·68 |
| 8 | 74·15 | +0·88 | −3·75 | +5·42 | −·012 | | 0·09 |
| 9 | 86·28 | +0·86 | −4·33 | +4·42 | −·013 | | 5·63 |
| 10 | 98·41 | +0·82 | −4·69 | +3·18 | −·013 | | 11·01 |
| 11 | 110·53 | +0·80 | −4·85 | +1·75 | −·014 | | 15·85 |
| 12 | 122·66 | +0·77 | −4·81 | +0·21 | −·015 | | 19·85 |
| 13 | 134·79 | +0·75 | −4·57 | −1·37 | −·015 | +·025 | 22·75 |
| 14 | 146·93 | +0·72 | −4·15 | −2·89 | −·015 | +·026 | 24·39 |
| 15 | 159·07 | +0·69 | −3·55 | −4·26 | −·015 | | 24·67 |
| 16 | 171·22 | +0·66 | −2·77 | −5·40 | −·014 | +·026 | 23·59 |

| Greenwich Midnight. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | Ω |
|---|---|---|---|---|---|---|---|
| 1906. | ° | ° | ° | ° | ° | ° | ° |
| Jan. 17 | 183·38 | +0·63 | −1·83 | −6·22 | −·013 | +·026 | 21·16 |
| 18 | 195·54 | +0·61 | −0·76 | −6·67 | −·012 | | 17·50 |
| 19 | 207·71 | +0·58 | +0·40 | −6·70 | −·010 | | 12·71 |
| 20 | 219·89 | +0·56 | +1·58 | −6·32 | −·010 | | 7·06 |
| 21 | 232·07 | +0·53 | +2·71 | −5·55 | −·009 | | 0·89 |
| 22 | 244·26 | +0·51 | +3·70 | −4·44 | −·009 | | 354·65 |
| 23 | 256·45 | +0·49 | +4·49 | −3·07 | −·009 | | 348·79 |
| 24 | 268·64 | +0·46 | +5·00 | −1·55 | −·009 | | 343·76 |
| 25 | 280·83 | +0·44 | +5·20 | +0·03 | −·010 | | 339·81 |
| 26 | 293·02 | +0·41 | +5·07 | +1·57 | −·010 | | 337·10 |
| 27 | 305·21 | +0·39 | +4·63 | +3·00 | −·011 | | 335·61 |
| 28 | 317·40 | +0·36 | +3·89 | +4·25 | −·013 | | 335·30 |
| 29 | 329·58 | +0·34 | +2·92 | +5·28 | −·015 | | 336·07 |
| 30 | 341·76 | +0·31 | +1·78 | +6·07 | −·017 | | 337·83 |
| 31 | 353·93 | +0·29 | +0·54 | +6·58 | −·018 | | 340·47 |
| Feb. 1 | 6·09 | +0·26 | −0·74 | +6·81 | −·020 | | 343·92 |
| 2 | 18·25 | +0·23 | −1·97 | +6·76 | −·023 | | 348·10 |
| 3 | 30·40 | +0·20 | −3·09 | +6·41 | −·025 | | 352·89 |
| 4 | 42·55 | +0·17 | −4·02 | +5·76 | −·026 | | 358·14 |
| 5 | 54·69 | +0·14 | −4·73 | +4·84 | −·027 | +·026 | 3·64 |
| 6 | 66·83 | +0·11 | −5·16 | +3·65 | −·028 | +·027 | 9·12 |
| 7 | 78·96 | +0·08 | −5·29 | +2·26 | −·029 | | 14·22 |
| 8 | 91·09 | +0·05 | −5·12 | +0·70 | −·030 | | 18·60 |
| 9 | 103·23 | +0·01 | −4·67 | −0·92 | −·030 | | 21·95 |
| 10 | 115·36 | −0·02 | −3·96 | −2·52 | −·030 | | 24·03 |
| 11 | 127·50 | −0·05 | −3·06 | −3·99 | −·030 | | 24·72 |
| 12 | 139·64 | −0·08 | −2·00 | −5·22 | −·029 | | 23·95 |
| 13 | 151·79 | −0·11 | −0·87 | −6·13 | −·027 | | 21·81 |
| 14 | 163·94 | −0·14 | +0·28 | −6·65 | −·026 | | 18·38 |
| 15 | 176·10 | −0·17 | +1·37 | −6·77 | −·025 | | 13·84 |
| 16 | 188·27 | −0·20 | +2·37 | −6·47 | −·025 | | 8·43 |
| 17 | 200·45 | −0·22 | +3·23 | −5·79 | −·023 | | 2·48 |
| 18 | 212·63 | −0·25 | +3·92 | −4·77 | −·023 | | 356·37 |
| 19 | 224·82 | −0·27 | +4·42 | −3·50 | −·023 | | 350·52 |
| 20 | 237·01 | −0·30 | +4·71 | −2·04 | −·023 | | 345·31 |
| 21 | 249·21 | −0·32 | +4·78 | −0·49 | −·023 | | 341·05 |
| 22 | 261·41 | −0·35 | +4·62 | +1·06 | −·024 | | 337·93 |
| 23 | 273·62 | −0·37 | +4·24 | +2·53 | −·025 | +·027 | 336·02 |

| Greenwich Midnight. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|
| 1906. | ° | ° | ° | ° | ° | ° | ° |
| Feb. 24 | 285·82 | −0·39 | +3·63 | +3·84 | −·025 | +·027 | 335·31 |
| 25 | 298·02 | −0·42 | +2·82 | +4·96 | −·026 | | 335·71 |
| 26 | 310·21 | −0·44 | +1·83 | +5·83 | −·028 | | 338·23 |
| 27 | 322·41 | −0·47 | +0·69 | +6·43 | −·030 | | 339·51 |
| 28 | 334·60 | −0·49 | −0·55 | +6·75 | −·032 | | 342·71 |
| Mar. 1 | 346·79 | −0·52 | −1·82 | +6·78 | −·033 | | 346·64 |
| 2 | 358·97 | −0·54 | −3·07 | +6·52 | −·035 | | 351·19 |
| 3 | 11·14 | −0·57 | −4·23 | +5·97 | −·037 | | 356·24 |
| 4 | 23·31 | −0·60 | −5·21 | +5·15 | −·038 | | 1·60 |
| 5 | 35·47 | −0·63 | −5·94 | +4·08 | −·039 | | 7·03 |
| 6 | 47·63 | −0·66 | −6·36 | +2·78 | −·040 | | 12·25 |
| 7 | 59·78 | −0·68 | −6·41 | +1·29 | −·040 | | 16·93 |
| 8 | 71·93 | −0·71 | −6·06 | −0·30 | −·040 | | 20·72 |
| 9 | 84·08 | −0·74 | −5·31 | −1·92 | −·040 | | 23·35 |
| 10 | 96·22 | −0·77 | −4·20 | −3·46 | −·039 | | 24·60 |
| 11 | 108·37 | −0·80 | −2·81 | −4·80 | −·038 | | 24·35 |
| 12 | 120·51 | −0·82 | −1·24 | −5·83 | −·037 | | 22·61 |
| 13 | 132·66 | −0·85 | +0·37 | −6·48 | −·036 | | 19·45 |
| 14 | 144·82 | −0·87 | +1·90 | −6·69 | −·035 | | 15·08 |
| 15 | 156·99 | −0·90 | +3·24 | −6·48 | −·033 | | 9·75 |
| 16 | 169·16 | −0·92 | +4·31 | −5·86 | −·032 | | 3·83 |
| 17 | 181·34 | −0·94 | +5·07 | −4·91 | −·031 | | 357·70 |
| 18 | 193·52 | −0·96 | +5·53 | −3·69 | −·030 | | 351·79 |
| 19 | 205·72 | −0·98 | +5·69 | −2·29 | −·030 | | 346·47 |
| 20 | 217·92 | −0·99 | +5·60 | −0·80 | −·030 | | 342 05 |
| 21 | 230·13 | −1·01 | +5·27 | +0·71 | −·030 | | 338·68 |
| 22 | 242·34 | −1·03 | +4·76 | +2·16 | −·030 | | 336·47 |
| 23 | 254·55 | −1·04 | +4·07 | +3·48 | −·031 | | 335·43 |
| 24 | 266·77 | −1·06 | +3·24 | +4·62 | −·032 | | 335·49 |
| 25 | 278·99 | −1·08 | +2·27 | +5·54 | −·034 | | 336·62 |
| 26 | 291·20 | −1·10 | +1·18 | +6·20 | −·035 | | 338·71 |
| 27 | 303·42 | −1·11 | −0·01 | +6·57 | −·036 | | 341·67 |
| 28 | 315·63 | −1·13 | −1·27 | +6·64 | −·038 | | 345·38 |
| 29 | 327·84 | −1·15 | −2·56 | +6·47 | −·039 | | 349·74 |
| 30 | 340·04 | −1·17 | −3·84 | +6·00 | −·040 | | 354·62 |
| 31 | 352·24 | −1·19 | −5·03 | +5·26 | −·041 | | 359·83 |
| Apr. 1 | 4·43 | −1·21 | −6·08 | +4·28 | −·042 | | 5·17 |
| 2 | 16·62 | −1·23 | −6·89 | +3·09 | −·043 | +·027 | 10·39 |

| Greenwich Midnight. 1906. | Selenographical Colong. of the Sun. | Selenographical Lat. of the Sun. | Geocentric Libration. Sel. Long. | Geocentric Libration. Lat. of the Earth. | Physical Libration. Long. | Physical Libration. Lat. | C. |
|---|---|---|---|---|---|---|---|
| Apr. 3 | 28°80 | −1°24 | −7°39 | +1°71 | −°043 | +°027 | 715°19 |
| 4 | 40·98 | −1·26 | −7·49 | +0·20 | −·043 | | 19·29 |
| 5 | 53·15 | −1·28 | −7·14 | −1·36 | −·043 | | 22·38 |
| 6 | 65·31 | −1·30 | −6·30 | −2·89 | −·042 | | 24·22 |
| 7 | 77·47 | −1·32 | −5·00 | −4·29 | −·041 | | 24·62 |
| 8 | 89·63 | −1·33 | −3·31 | −5·42 | −·040 | | 23·50 |
| 9 | 101·79 | −1·35 | −1·37 | −6·20 | −·038 | | 20·86 |
| 10 | 113·95 | −1·36 | +0·66 | −6·54 | −·037 | | 16·81 |
| 11 | 126·12 | −1·37 | +2·59 | −6·43 | −·035 | | 11·61 |
| 12 | 138·29 | −1·39 | +4·25 | −5·89 | −·033 | | 5·64 |
| 13 | 150·47 | −1·40 | +5·54 | −4·97 | −·032 | | 359·33 |
| 14 | 162·65 | −1·41 | +6·41 | −3·77 | −·030 | | 353·19 |
| 15 | 174·85 | −1·41 | +6·84 | −2·39 | −·029 | | 347·62 |
| 16 | 187·04 | −1·42 | +6·89 | −0·92 | −·028 | | 342·94 |
| 17 | 199·25 | −1·43 | +6·60 | +0·52 | −·029 | | 339·34 |
| 18 | 211·47 | −1·43 | +6·04 | +1·95 | −·029 | | 336·89 |
| 19 | 223·68 | −1·44 | +5·28 | +3·25 | −·029 | | 335·59 |
| 20 | 235·91 | −1·45 | +4·36 | +4·39 | −·029 | | 335·41 |
| 21 | 248·13 | −1·45 | +3·32 | +5·31 | −·030 | | 336·26 |
| 22 | 260·37 | −1·46 | +2·19 | +5·98 | −·031 | | 338·09 |
| 23 | 272·60 | −1·46 | +1·00 | +6·38 | −·032 | | 340·82 |
| 24 | 284·83 | −1·47 | −0·25 | +6·50 | −·034 | | 344·33 |
| 25 | 297·07 | −1·48 | −1·54 | +6·34 | −·034 | | 348·53 |
| 26 | 309·29 | −1·48 | −2·83 | +5·90 | −·035 | | 353·28 |
| 27 | 321·52 | −1·49 | −4·10 | +5·20 | −·037 | | 358·40 |
| 28 | 333·75 | −1·50 | −5·30 | +4·27 | −·038 | | 3·68 |
| 29 | 345·96 | −1·50 | −6·37 | +3·13 | −·038 | | 8·89 |
| 30 | 358·17 | −1·51 | −7·23 | +1·83 | −·038 | | 13·75 |
| May 1 | 10·38 | −1·51 | −7·80 | +0·45 | −·038 | | 18·00 |
| 2 | 22·57 | −1·52 | −8·00 | −1·04 | −·038 | | 21·37 |
| 3 | 34·77 | −1·52 | −7·74 | −2·52 | −·037 | | 23·64 |
| 4 | 46·95 | −1·53 | −6·99 | −3·90 | −·036 | | 24·62 |
| 5 | 59·14 | −1·53 | −5·73 | −5·08 | −·035 | | 24·16 |
| 6 | 71·31 | −1·54 | −4·01 | −5·96 | −·033 | | 22·21 |
| 7 | 83·49 | −1·54 | −1·95 | −6·43 | −·031 | | 18·76 |
| 8 | 95·66 | −1·54 | +0·25 | −6·45 | −·029 | | 13·97 |
| 9 | 107·83 | −1·53 | +2·41 | −6·00 | −·027 | | 8·14 |
| 10 | 120·01 | −1·53 | +4·31 | −5·14 | −·025 | +·027 | 1·72 |

| Greenwich Midnight. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|
| 1906. | ° | ° | ° | ° | ° | ° | ° |
| May 11 | 132·20 | −1·53 | +5·83 | −3·96 | −·023 | +·027 | 355·24 |
| 12 | 144·39 | −1·52 | +6·87 | −2·55 | −·022 | | 349·25 |
| 13 | 156·58 | −1·52 | +7·42 | −1·04 | −·021 | | 344·13 |
| 14 | 168·78 | −1·51 | +7·52 | +0·48 | −·020 | | 340·14 |
| 15 | 181·00 | −1·50 | +7·22 | +1·94 | −·019 | | 337·37 |
| 16 | 193·21 | −1·50 | +6·60 | +3·26 | −·018 | | 335·80 |
| 17 | 205·44 | −1·49 | +5·72 | +4·41 | −·020 | | 335·37 |
| 18 | 217·67 | −1·48 | +4·69 | +5·33 | −·021 | | 335·99 |
| 19 | 229·90 | −1·48 | +3·53 | +6·01 | −·022 | | 337·60 |
| 20 | 242·14 | −1·47 | +2·30 | +6·43 | −·023 | | 340·11 |
| 21 | 254·39 | −1·46 | +1·03 | +6·56 | −·024 | | 343·43 |
| 22 | 266·63 | −1·46 | −0·25 | +6·41 | −·024 | | 347·46 |
| 23 | 278·88 | −1·45 | −1·53 | +5·98 | −·025 | | 352·09 |
| 24 | 291·12 | −1·45 | −2·78 | +5·29 | −·025 | | 357·14 |
| 25 | 303·36 | −1·44 | −3·99 | +4·37 | −·026 | | 2·42 |
| 26 | 315·60 | −1·43 | −5·11 | +3·24 | −·026 | | 7·67 |
| 27 | 327·84 | −1·42 | −6·11 | +1·95 | −·027 | | 12·60 |
| 28 | 340·07 | −1·42 | −6·91 | +0·55 | −·027 | | 16·98 |
| 29 | 352·30 | −1·41 | −7·47 | −0·91 | −·026 | | 20·53 |
| 30 | 4·52 | −1·40 | −7·69 | −2·36 | −·025 | | 23·07 |
| 31 | 16·73 | −1·39 | −7·51 | −3·72 | −·023 | | 24·43 |
| June 1 | 28·93 | −1·39 | −6·88 | −4·91 | −·022 | | 24·49 |
| 2 | 41·13 | −1·37 | −5·78 | −5·84 | −·020 | | 23·14 |
| 3 | 53·33 | −1·36 | −4·23 | −6·41 | −·018 | | 20·37 |
| 4 | 65·52 | −1·35 | −2·34 | −6·56 | −·017 | | 16·21 |
| 5 | 77·70 | −1·34 | −0·25 | −6·25 | −·015 | | 10·84 |
| 6 | 89·89 | −1·32 | +1·85 | −5·49 | −·012 | | 4·61 |
| 7 | 102·07 | −1·30 | +3·77 | −4·35 | −·010 | | 357·99 |
| 8 | 114·26 | −1·29 | +5·36 | −2·95 | −·008 | | 351·59 |
| 9 | 126·45 | −1·27 | +6·52 | −1·38 | −·007 | | 345·93 |
| 10 | 138·65 | −1·25 | +7·20 | +0·22 | −·005 | | 341·38 |
| 11 | 150·85 | −1·23 | +7·40 | +1·76 | −·005 | | 338·12 |
| 12 | 163·06 | −1·22 | +7·19 | +3·16 | −·004 | | 336·14 |
| 13 | 175·28 | −1·20 | +6·62 | +4·37 | −·003 | | 335·39 |
| 14 | 187·50 | −1·18 | +5·77 | +5·35 | −·004 | | 335·76 |
| 15 | 199·73 | −1·16 | +4·72 | +6·08 | −·006 | | 337·14 |
| 16 | 211·97 | −1·14 | +3·53 | +6·51 | −·007 | | 339·43 |
| 17 | 224·21 | −1·12 | +2·26 | +6·67 | −·007 | +·027 | 342·55 |

| Greenwich Midnight. 1906. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|
| June 18 | 236°·45 | −1°·11 | +0°·97 | +6°·55 | −°·008 | +°·027 | 346°·41 |
| 19 | 248·70 | −1·09 | −0·31 | +6·14 | −·009 | | 350·90 |
| 20 | 260·95 | −1·07 | −1·54 | +5·47 | −·009 | | 355·87 |
| 21 | 273·21 | −1·06 | −2·71 | +4·55 | −·010 | | 1·13 |
| 22 | 285·46 | −1·04 | −3·78 | +3·42 | −·011 | | 6·44 |
| 23 | 297·71 | −1·02 | −4·74 | +2·12 | −·010 | | 11·50 |
| 24 | 309·96 | −1·01 | −5·54 | +0·70 | −·010 | | 16·04 |
| 25 | 322·20 | −0·99 | −6·16 | −0·78 | −·010 | | 19·80 |
| 26 | 334·44 | −0·97 | −6·54 | −2·24 | −·009 | | 22·58 |
| 27 | 346·67 | −0·95 | −6·65 | −3·62 | −·008 | | 24·21 |
| 28 | 358·90 | −0·93 | −6·43 | −4·83 | −·007 | | 24·59 |
| 29 | 11·12 | −0·92 | −5·84 | −5·80 | −·005 | | 23·66 |
| 30 | 23·33 | −0·90 | −4·89 | −6·44 | −·003 | | 21·40 |
| July 1 | 35·54 | −0·87 | −3·59 | −6·69 | ·000 | | 17·83 |
| 2 | 47·74 | −0·85 | −2·02 | −6·52 | +·002 | | 13·04 |
| 3 | 59·93 | −0·83 | −0·26 | −5·90 | +·003 | | 7·25 |
| 4 | 72·13 | −0·80 | +1·52 | −4·87 | +·005 | | 0·84 |
| 5 | 84·31 | −0·78 | +3·20 | −3·53 | +·008 | | 354·31 |
| 6 | 96·50 | −0·75 | +4·64 | −1·96 | +·010 | | 348·24 |
| 7 | 108·69 | −0·72 | +5·73 | −0·30 | +·011 | | 343·11 |
| 8 | 120·89 | −0·69 | +6·42 | +1·34 | +·012 | | 339·25 |
| 9 | 133·09 | −0·66 | +6·69 | +2·85 | +·013 | | 336·72 |
| 10 | 145·29 | −0·64 | +6·56 | +4·17 | +·014 | | 335·53 |
| 11 | 157·50 | −0·61 | +6·07 | +5·24 | +·014 | | 335·55 |
| 12 | 169·71 | −0·58 | +5·29 | +6·05 | +·014 | | 336·66 |
| 13 | 181·94 | −0·56 | +4·27 | +6·56 | +·013 | +·027 | 338·72 |
| 14 | 194·17 | −0·54 | +3·10 | +6·79 | +·012 | +·026 | 341·62 |
| 15 | 206·40 | −0·51 | +1·84 | +6·72 | +·012 | | 345·29 |
| 16 | 218·64 | −0·49 | +0·56 | +6·36 | +·011 | | 349·61 |
| 17 | 230·88 | −0·46 | −0·69 | +5·73 | +·010 | | 354·45 |
| 18 | 243·13 | −0·44 | −1·86 | +4·85 | +·010 | | 359·65 |
| 19 | 255·38 | −0·42 | −2·91 | +3·74 | +·009 | | 4·99 |
| 20 | 267·63 | −0·39 | −3·81 | +2·44 | +·009 | | 10·19 |
| 21 | 279·89 | −0·37 | −4·53 | +1·00 | +·009 | | 14·94 |
| 22 | 292·13 | −0·35 | −5·04 | −0·50 | +·009 | | 18·96 |
| 23 | 304·38 | −0·33 | −5·34 | −2·01 | +·010 | | 22·02 |
| 24 | 316·63 | −0·30 | −5·40 | −3·43 | +·011 | | 23·92 |
| 25 | 328·87 | −0·28 | −5·22 | −4·69 | +·012 | +·026 | 24·59 |

| Greenwich Midnight. 1906. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° |
| July 26 | 341·10 | −0·26 | −4·78 | −5·71 | +·013 | +·026 | 23·96 |
| 27 | 353·33 | −0·23 | −4·10 | −6·42 | +·015 | | 22·03 |
| 28 | 5·55 | −0·21 | −3·19 | −6·75 | +·016 | | 18·86 |
| 29 | 17·76 | −0·18 | −2·07 | −6·68 | +·018 | | 14·51 |
| 30 | 29·97 | −0·15 | −0·81 | −6·19 | +·020 | | 9·16 |
| 31 | 42·17 | −0·12 | +0·53 | −5·30 | +·022 | | 3·10 |
| Aug. 1 | 54·36 | −0·09 | +1·87 | −4·06 | +·024 | | 356·73 |
| 2 | 66·55 | −0·06 | +3·12 | −2·58 | +·025 | +·026 | 350·54 |
| 3 | 78·74 | −0·03 | +4·19 | −0·94 | +·027 | +·025 | 345·06 |
| 4 | 90·92 | 0·00 | +5·02 | +0·73 | +·028 | | 340·67 |
| 5 | 103·11 | +0·03 | +5·55 | +2·32 | +·029 | | 337·59 |
| 6 | 115·30 | +0·06 | +5·74 | +3·75 | +·030 | | 335·87 |
| 7 | 127·49 | +0·09 | +5·60 | +4·94 | +·030 | | 335·44 |
| 8 | 139·69 | +0·12 | +5·15 | +5·85 | +·030 | | 336·18 |
| 9 | 151·89 | +0·15 | +4·40 | +6·47 | +·029 | | 337·95 |
| 10 | 164·10 | +0·18 | +3·43 | +6·79 | +·028 | | 340·61 |
| 11 | 176·31 | +0·20 | +2·28 | +6·80 | +·028 | | 344·08 |
| 12 | 188·53 | +0·23 | +1·03 | +6·52 | +·027 | | 348·21 |
| 13 | 200·76 | +0·26 | −0·24 | +5·96 | +·027 | | 352·90 |
| 14 | 212·99 | +0·28 | −1·48 | +5·15 | +·027 | | 357·99 |
| 15 | 225·22 | +0·30 | −2·60 | +4·10 | +·025 | | 3·29 |
| 16 | 237·46 | +0·33 | −3·56 | +2·84 | +·025 | | 8·55 |
| 17 | 249·70 | +0·35 | −4·29 | +1·44 | +·025 | | 13·48 |
| 18 | 261·95 | +0·37 | −4·77 | −0·06 | +·025 | | 17·80 |
| 19 | 274·19 | +0·39 | −4·96 | −1·59 | +·025 | | 21·21 |
| 20 | 286·43 | +0·42 | −4·86 | −3·07 | +·025 | | 23·49 |
| 21 | 298·68 | +0·44 | −4·49 | −4·40 | +·026 | | 24·52 |
| 22 | 310·91 | +0·46 | −3·88 | −5·49 | +·027 | | 24·20 |
| 23 | 323·15 | +0·49 | −3·06 | −6·28 | +·028 | | 22·55 |
| 24 | 335·38 | +0·51 | −2·11 | −6·69 | +·030 | | 19·63 |
| 25 | 347·60 | +0·54 | −1·07 | −6·70 | +·031 | | 15·55 |
| 26 | 359·81 | +0·56 | 0·00 | −6·30 | +·033 | | 10·47 |
| 27 | 12·01 | +0·59 | +1·07 | −5·51 | +·035 | | 4·67 |
| 28 | 24·21 | +0·61 | +2·07 | −4·38 | +·037 | | 358·48 |
| 29 | 36·40 | +0·64 | +2·97 | −2·99 | +·038 | | 352·36 |
| 30 | 48·59 | +0·67 | +3·75 | −1·44 | +·040 | | 346·76 |
| 31 | 60·77 | +0·70 | +4·37 | +0·19 | +·040 | | 342·07 |
| Sept. 1 | 72·95 | +0·73 | +4·80 | +1·78 | +·041 | +·025 | 338·57 |

| Greenwich Midnight. 1906. | | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|---|
| | | ° | ° | ° | ° | ° | ° | ° |
| Sept. | 2 | 85·13 | +0·75 | +5·02 | +3·25 | +·042 | +·025 | 336·37 |
| | 3 | 97·30 | +0·78 | +5·00 | +4·51 | +·042 | | 335·49 |
| | 4 | 109·48 | +0·81 | +4·73 | +5·52 | +·042 | | 335·81 |
| | 5 | 121·66 | +0·83 | +4·20 | +6·23 | +·042 | | 337·23 |
| | 6 | 133·85 | +0·86 | +3·43 | +6·64 | +·041 | | 339·62 |
| | 7 | 146·03 | +0·88 | +2·44 | +6·74 | +·040 | | 342·85 |
| | 8 | 158·22 | +0·90 | +1·29 | +6·54 | +·039 | | 346·78 |
| | 9 | 170·42 | +0·92 | +0·02 | +6·06 | +·038 | | 351·30 |
| | 10 | 182·63 | +0·94 | −1·28 | +5·33 | +·037 | | 356·26 |
| | 11 | 194·83 | +0·96 | −2·54 | +4·36 | +·035 | | 1·47 |
| | 12 | 207·05 | +0·98 | −3·67 | +3·19 | +·035 | | 6·73 |
| | 13 | 219·27 | +1·00 | −4·60 | +1·86 | +·034 | | 11·77 |
| | 14 | 231·49 | +1·02 | −5·24 | +0·41 | +·033 | | 16·31 |
| | 15 | 243·72 | +1·03 | −5·55 | −1·10 | +·033 | | 20·07 |
| | 16 | 255·95 | +1·05 | −5·48 | −2·59 | +·033 | | 22·78 |
| | 17 | 268·18 | +1·06 | −5·02 | −3·97 | +·034 | | 24·29 |
| | 18 | 280·41 | +1·08 | −4·21 | −5·14 | +·035 | | 24·42 |
| | 19 | 292·64 | +1·10 | −3·12 | −6·01 | +·035 | | 23·16 |
| | 20 | 304·87 | +1·11 | −1·82 | −6·52 | +·036 | | 20·54 |
| | 21 | 317·09 | +1·13 | −0·46 | −6·61 | +·038 | | 16·66 |
| | 22 | 329·31 | +1·15 | +0·88 | −6·27 | +·039 | | 11·72 |
| | 23 | 341·51 | +1·17 | +2·10 | −5·54 | +·040 | | 6·00 |
| | 24 | 353·72 | +1·19 | +3·14 | −4·47 | +·042 | +·025 | 359·86 |
| | 25 | 5·91 | +1·21 | +3·97 | −3·15 | +·043 | +·024 | 353·72 |
| | 26 | 18·10 | +1·23 | +4·58 | −1·66 | +·045 | | 348·04 |
| | 27 | 30·27 | +1·25 | +4·98 | −0·10 | +·047 | | 343·19 |
| | 28 | 42·45 | +1·27 | +5·19 | +1·45 | +·047 | | 339·44 |
| | 29 | 54·62 | +1·28 | +5·22 | +2·90 | +·047 | | 336·92 |
| | 30 | 66·78 | +1·30 | +5·08 | +4·17 | +·047 | | 335·65 |
| Oct. | 1 | 78·95 | +1·32 | +4·76 | +5·21 | +·047 | | 335·61 |
| | 2 | 91·11 | +1·33 | +4·25 | +5·98 | +·046 | | 336·67 |
| | 3 | 103·27 | +1·35 | +3·56 | +6·42 | +·045 | | 338·76 |
| | 4 | 115·43 | +1·36 | +2·68 | +6·60 | +·045 | | 341·73 |
| | 5 | 127·60 | +1·38 | +1·62 | +6·46 | +·043 | | 345·46 |
| | 6 | 139·77 | +1·39 | +0·41 | +6·05 | +·042 | | 349·81 |
| | 7 | 151·94 | +1·40 | −0·89 | +5·37 | +·040 | | 354·63 |
| | 8 | 164·12 | +1·41 | −2·24 | +4·46 | +·038 | | 359·76 |
| | 9 | 176·31 | +1·42 | −3·55 | +3·36 | +·037 | +·024 | 4·97 |

| Greenwich Midnight. | Selenographical Colong. of the Sun. | Lat. | Geocentric Libration. Sel. Long. of the Earth. | Lat. | Physical Libration. Long. | Lat. | O. |
|---|---|---|---|---|---|---|---|
| 1906. | ° | ° | ° | ° | ° | ° | ° |
| Oct. 10 | 188·50 | +1·42 | −4·73 | +2·10 | +·037 | +·024 | 10·04 |
| 11 | 200·69 | +1·43 | −5·71 | +0·72 | +·037 | | 14·72 |
| 12 | 212·89 | +1·44 | −6·37 | −0·72 | +·036 | | 18·72 |
| 13 | 225·09 | +1·44 | −6·65 | −2·17 | +·035 | | 21·83 |
| 14 | 237·30 | +1·45 | −6·47 | −3·55 | +·035 | | 23·81 |
| 15 | 249·51 | +1·45 | −5·82 | −4·76 | +·035 | | 24·51 |
| 16 | 261·73 | +1·46 | −4·71 | −5·72 | +·036 | | 23·81 |
| 17 | 273·94 | +1·46 | −3·22 | −6·32 | +·037 | | 21·68 |
| 18 | 286·16 | +1·47 | −1·49 | −6·51 | +·038 | | 18·17 |
| 19 | 298·37 | +1·48 | +0·32 | −6·26 | +·039 | | 13·44 |
| 20 | 310·58 | +1·48 | +2·05 | −5·58 | +·040 | | 7·75 |
| 21 | 322·78 | +1·49 | +3·57 | −4·54 | +·041 | | 1·51 |
| 22 | 334·98 | +1·50 | +4·78 | −3·23 | +·042 | | 354·78 |
| 23 | 347·16 | +1·50 | +5·65 | −1·74 | +·044 | | 349·26 |
| 24 | 359·35 | +1·51 | +6·18 | −0·18 | +·044 | | 344·18 |
| 25 | 11·52 | +1·52 | +6·40 | +1·35 | +·045 | | 340·18 |
| 26 | 23·68 | +1·52 | +6·35 | +2·78 | +·045 | | 337·40 |
| 27 | 35·85 | +1·53 | +6·08 | +4·04 | +·045 | | 335·86 |
| 28 | 48·00 | +1·53 | +5·63 | +5·08 | +·045 | | 335·53 |
| 29 | 60·16 | +1·53 | +5·01 | +5·85 | +·044 | | 336·32 |
| 30 | 72·30 | +1·53 | +4·25 | +6·35 | +·043 | | 338·11 |
| 31 | 84·45 | +1·54 | +3·35 | +6·53 | +·042 | | 340·81 |
| Nov. 1 | 96·60 | +1·53 | +2·31 | +6·43 | +·040 | | 344·32 |
| 2 | 108·74 | +1·53 | +1·14 | +6·04 | +·038 | | 348·50 |
| 3 | 120·89 | +1·53 | −0·13 | +5·38 | +·037 | +·024 | 353·20 |
| 4 | 133·04 | +1·52 | −1·48 | +4·50 | +·035 | +·023 | 358·23 |
| 5 | 145·20 | +1·52 | −2·86 | +3·43 | +·033 | | 3·45 |
| 6 | 157·36 | +1·51 | −4·20 | +2·20 | +·032 | | 8·54 |
| 7 | 169·52 | +1·51 | −5·43 | +0·87 | +·030 | | 13·30 |
| 8 | 181·69 | +1·50 | −6·47 | −0·53 | +·029 | | 17·46 |
| 9 | 193·87 | +1·49 | −7·21 | −1·94 | +·028 | | 20·82 |
| 10 | 206·04 | +1·49 | −7·55 | −3·29 | +·028 | | 23·18 |
| 11 | 218·23 | +1·48 | −7·43 | −4·51 | +·028 | | 24·36 |
| 12 | 230·42 | +1·47 | −6·80 | −5·51 | +·028 | | 24·26 |
| 13 | 242·62 | +1·46 | −5·65 | −6·21 | +·028 | | 22·78 |
| 14 | 254·82 | +1·45 | −4·04 | −6·51 | +·028 | | 19·88 |
| 15 | 267·02 | +1·45 | −2·09 | −6·38 | +·029 | | 15·63 |
| 16 | 279·22 | +1·44 | +0·01 | −5·80 | +·030 | +·023 | 10·21 |

| Greenwich. Midnight. 1906. | Selenographical Colong. of the Sun. | Lat. of the Sun. | Geocentric Libration. Sel. Long. of the Earth. | Lat. of the Earth. | Physical Libration. Long. | Lat. | C. |
|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° |
| Nov. 17 | 291·42 | +1·44 | +2·07 | −4·80 | +·031 | +·023 | 3·97 |
| 18 | 303·61 | +1·43 | +3·92 | −3·48 | +·032 | | 357·39 |
| 19 | 315·80 | +1·42 | +5·42 | −1·94 | +·033 | | 351·06 |
| 20 | 327·99 | +1·41 | +6·51 | −0·33 | +·033 | | 345·51 |
| 21 | 340·17 | +1·41 | +7·16 | +1·27 | +·034 | | 341·09 |
| 22 | 352·34 | +1·40 | +7·42 | +2·75 | +·034 | +·023 | 337·95 |
| 23 | 4·50 | +1·39 | +7·32 | +4·04 | +·035 | +·022 | 336·12 |
| 24 | 16·66 | +1·38 | +6·93 | +5·10 | +·035 | | 335·52 |
| 25 | 28·81 | +1·37 | +6·29 | +5·89 | +·033 | | 336·06 |
| 26 | 40·96 | +1·36 | +5·47 | +6·40 | +·032 | | 337·62 |
| 27 | 53·10 | +1·34 | +4·50 | +6·60 | +·031 | | 340·09 |
| 28 | 65·24 | +1·33 | +3·41 | +6·51 | +·030 | | 343·38 |
| 29 | 77·37 | +1·31 | +2·22 | +6·24 | +·028 | | 347·38 |
| 30 | 89·51 | +1·30 | +0·96 | +5·50 | +·026 | | 351·95 |
| Dec. 1 | 101·64 | +1·28 | −0·36 | +4·62 | +·024 | | 356·93 |
| 2 | 113·78 | +1·26 | −1·72 | +3·55 | +·022 | | 2·15 |
| 3 | 125·92 | +1·24 | −3·08 | +2·31 | +·020 | | 7·26 |
| 4 | 138·06 | +1·22 | −4·39 | +0·97 | +·018 | | 12·11 |
| 5 | 150·20 | +1·20 | −5·58 | −0·42 | +·017 | | 16·42 |
| 6 | 162·35 | +1·18 | −6·60 | −1·82 | +·015 | | 19·96 |
| 7 | 174·50 | +1·16 | −7·35 | −3·17 | +·014 | | 22·57 |
| 8 | 186·66 | +1·14 | −7·77 | −4·39 | +·013 | | 24·09 |
| 9 | 198·83 | +1·12 | −7·76 | −5·42 | +·013 | +·022 | 24·42 |
| 10 | 211·00 | +1·10 | −7·28 | −6·18 | +·014 | +·021 | 23·51 |
| 11 | 223·20 | +1·08 | −6·30 | −6·60 | +·014 | | 21·27 |
| 12 | 235·36 | +1·06 | −4·85 | −6·61 | +·015 | | 17·70 |
| 13 | 247·55 | +1·04 | −3·02 | −6·17 | +·015 | | 12·87 |
| 14 | 259·74 | +1·02 | −0·95 | −5·30 | +·015 | | 6·99 |
| 15 | 271·93 | +1·00 | +1·18 | −4·03 | +·016 | | 0·43 |
| 16 | 284·12 | +0·98 | +3·18 | −2·49 | +·017 | | 353·78 |
| 17 | 296·31 | +0·96 | +4·91 | −0·80 | +·019 | | 347·66 |
| 18 | 308·50 | +0·95 | +6·24 | +0·91 | +·019 | | 342·58 |
| 19 | 320·68 | +0·93 | +7·13 | +2·51 | +·019 | | 338·86 |
| 20 | 332·85 | +0·91 | +7·58 | +3·92 | +·019 | | 336·55 |
| 21 | 345·02 | +0·89 | +7·60 | +5·07 | +·018 | | 335·59 |
| 22 | 357·18 | +0 87 | +7·26 | +5·93 | +·018 | | 335·85 |
| 23 | 9·34 | +0·84 | +6·60 | +6·49 | +·017 | | 337·18 |
| 24 | 21·49 | +0·82 | +5·71 | +6·74 | +·016 | +·021 | 339·45 |

# LIST OF ADDITIONS

# TO THE LIBRARY

## OF THE SOCIETY

## JUNE 1904 TO JUNE 1905.

*An asterisk (*) indicates that the work is an excerpt.*

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## PHOTOGRAPHS, &c., PRESENTED TO THE SOCIETY.

**Andrews (Wm.)**—Model of the Lunar Crater Eratosthenes, by Henry Blunt.

**Flowers (F.)**—Map of the Witwatersrand goldfields, by F. Flowers.

**Hamburg Observatory**—Chart of stars, &c., in the neighbourhood of the Sun at the time of the eclipse of 1905 Aug. 29–30.

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**Johnson (S. J.)**—Map of England, showing approximate track of the total solar eclipse of 1927 June 9.

**Little (L. S.)**—Old ring dial.

**Lowell (P.)**—Spectrograms taken to determine the rotation period of planets (Venus, Mars, Jupiter, and Saturn).

**Minister of Public Instruction, Paris**—Seven enlargements from photographs of the Moon, taken by MM. Lœwy and Puiseux (heliogravure prints).

**Nielsen (V.)**—Five photographs of instruments, &c., at the Urania Observatory, Copenhagen.

**Noble (Mrs. Irving)**—Wire micrometer, by Dallmeyer, formerly belonging to the late Captain Noble.

**Roberts (Mrs. Isaac)**—Series of twenty-four transparencies from photographs of nebulæ, taken by the late Dr. Isaac Roberts ; also a portrait of Dr. Roberts.

**Royal Observatory, Greenwich**—Six original negatives of the Sun, taken 1905 January and February.

**Waugh (W. R.)**—Photograph of Sir Isaac Newton's house.

# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

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Sir J. N. Lockyer and Mr. F. E. Baxandall. Enhanced Lines of Titanium, Iron, and Chromium in the Fraunhoferic Spectrum . . . . [2]

"Enhanced Lines of Titanium, Iron, and Chromium in the Fraunhoferic Spectrum." By Sir J. Norman Lockyer, K.C.B., LL.D., F.R.S., and F. E. Baxandall, A.R.C.S. Received July 13, 1904.

In previous publications it has been shown that the enhanced lines of some of the metals are prominent in the spectra of $\alpha$ Cygni* and the sun's chromosphere,† while it is generally recognised that the lines in the Fraunhoferic spectrum are mainly the equivalents of lines in the arc spectra of metals. In connection with the work on enhanced lines it has been noted that some of them, at least, appear to correspond with comparatively weak solar lines to which Rowland has attached no origin. With the object of possibly tracing some of the unorigined solar lines to their source, a careful comparison has been made between the enhanced lines shown in the photographic spark spectra of titanium, iron, and chromium, and the solar lines. The photographs used for this purpose were all taken with a Rowland grating, under exactly similar conditions, and on such a scale that the length of spectrum between K and F is about 14 inches (35 cms.). The chemical elements named were first selected for investigation, because they furnish by far the greater number of enhanced lines which have been shown to occur in the spectrum of $\alpha$ Cygni. It was an easy matter, owing to the many solar coincidences with lines of these elements, to adjust the compared photographs and get the spectrum lines in proper alignment.

It was found that many of the enhanced lines fell exactly and squarely on isolated lines of the solar spectrum, and in these cases the solar wave-lengths were adopted, and the identification considered established. If, however, for any of these solar lines Rowland had given alternative origins, special comparisons were made of the enhanced line photograph and those of the metals given by Rowland. Notes were made as to the agreement or non-agreement of the metallic lines involved, and also of the relative intensities in their individual spectra, so that due weights could be given to the respective metallic lines which were thought to conjointly produce compound solar lines.

Where there was any doubt as to the exact coincidence of a metallic and solar line, or where by the close grouping of several solar lines it was not possible to say by direct comparison to which solar line the metallic line corresponded, careful measures were made of the metallic line, and its wave-length found by interpolation between closely adjacent lines of known wave-length. The resulting wave-lengths

* 'Roy. Soc. Proc.,' vol. 64, p. 321.
† 'Roy. Soc. Proc.,' vol. 68, p. 178.

were then compared with Rowland's solar wave-lengths, and in cases of close agreement with solar lines it was deemed probable that the two lines were really identical. In this connection, however, the relative intensities of the solar and enhanced lines were, to a great extent, taken into account in judging whether a solar line could be accepted as the analogue of a metallic line.

The three elements investigated are dealt with separately. The tables show the wave-lengths of the enhanced lines as reduced from the most recent and best photographs, their intensities in spark and arc spectra, the wave-lengths of Rowland's solar lines to which they probably correspond, and the origins, if any, to which Rowland has attributed such solar lines.

The wave-lengths of some of the enhanced lines differ in the second decimal place from those published* previously for the same lines. More weight can be given to the present wave-lengths, as in the photographs from which they have been reduced the lines are more sharply defined than in the earlier photographs employed. In the case of chromium a much more extended list of enhanced lines than the previous one has been obtained.

The numbers in the last column refer to the notes at the end of each table.

Titanium.

| λ. Enhanced Ti lines. | Intensity. | | Fraunhoferic lines (Rowland). | | Rowland's origin. | Notes appended. |
|---|---|---|---|---|---|---|
| | Spark, max. 10. | Arc, max. 10. | λ. | Int., max. 1000. | | |
| 3813·54 | 4 | 1—2 | 3813·54 | 2 | C | 1 |
| 3814·72 | 5 | 2—3 | 3814·74 | 3 | C | 2 |
| 3836·23 | 4 | 1—2 | 3836·23 | 2 | — | 3 |
| 3900·68 | 10 | 4 | 3900·68 | 5 | Ti-Fe-Zr | [1] |
| 3913·61 | 10 | 4 | 3913·61 | 5 | Ti-Fe | [2] |
| 3932·16 | 4 | trace | 3932·16 | 1 | Ti | |
| 3987·75 | 1 | 0 | 3987·76 | 2 | Ti ? | |
| 4012·54 | 5 | 1 | 4012·54 | 4 | Ti | |
| 4025·29 | 3 | 1 | 4025·29 | 3 | Ti | |
| 4028·50 | 6 | 1 | 4028·50 | 4 | Ti | |
| 4053·98 | 5 | trace | 4053·98 | 3 | Fe-Ti | [3] |
| 4055·19 | 2 | 1 | 4055·19 | 3 | Ti-Fe | [4] |
| 4161·70 | 2—3 | 0 | 4161·68 | 4 | — | 4 |
| 4163·82 | 10 | 2 | 4163·82 | 4 | Ti, Cr | [5] |
| 4172·07 | 10 | 1 | 4172·07 | 2 | Ti-Fe | [6] |
| 4173·70 | 3 | 0 | 4173·71 | 3 | — | [7] |
| 4174·20 | 2 | 0 | 4174·24 | 0 | — | |
| 4184·49 | 1 | 0 | 4184·47 | 2 | — | [8] |

* 'Roy. Soc. Proc.,' vol. 65, p. 451.

Titanium—*continued.*

| λ. Enhanced Ti lines. | Intensity. | | Fraunhoferic lines (Rowland). | | Rowland's origin. | Notes appended. |
|---|---|---|---|---|---|---|
| | Spark, max. 10. | Arc, max. 10. | λ. | Int. max. 1000. | | |
| 4227·46 | 2 | 0 | 4227·47 | 1 | — | 5 |
| 4290·38 | 6 | 2 | 4290·38 | 2 | Ti | |
| 4294·20 | 7 | 3 | 4294·20 | 2 | Ti | |
| 4300·21 | 6 | 1—2 | 4300·21 | 3 | Ti | |
| 4302·09 | 3 | 1—2 | 4302·09 | 2 | Ti | |
| 4308·06 | 7 | 1—2 | 4308·08 | 6 | Fe | 6 |
| 4313·03 | 7 | 1—2 | 4313·03 | 3 | Ti | |
| 4315·14 | 8 | 1 | 4315·14 | 3 | Ti | |
| 4316·96 | 2 | 0 | 4316·96 | 1 | Ti? | |
| 4321·12 | 3 | 1 | 4321·12 | 2 | — | |
| 4330·40 | 2 | trace | 4330·41 | 1 | — | |
| 4330·87 | 2 | trace | 4330·87 | 2 | Ti-Ni | [9] |
| 4338·08 | 8 | 4 | 4338·08 | 4 | Ti | |
| 4341·53 | 3 | 1 | 4341·53 | 2 | Ti? | |
| 4374·96 | 3 | 0 | 4374·98 | 0 | Zr | [10] |
| 4387·01 | 5 | trace | 4387·01 | 1 | Ti? | |
| 4391·19 | 1—2 | trace | 4391·19 | 1 | Ti | |
| 4395·20 | 9 | 5 | 4395·20 | 3 | Ti | |
| 4396·01 | 2 | trace | 4396·01 | 1 | Ti | |
| 4399·94 | 7 | 3 | 4399·94 | 3 | Ti-Cr | [11] |
| 4411·24 | 5 | trace | 4411·24 | 1 | Cr | [12] |
| 4417·88 | 6 | 2 | 4417·88 | 3 | Ti | |
| 4421·93 | 3 | 2 | 4421·93 | 00 | Ti | |
| 4443·98 | 9 | 4 | 4443·98 | 5 | Ti | |
| 4450·65 | 3 | 1 | 4450·65 | 2 | Ti? | 7 |
| 4464·62 | 3 | 1 | 4464·62 | 2 | Ti? | 8 |
| 4468·66 | 9 | 4 | 4468·66 | 5 | Ti | |
| 4488·49 | 5 | 1 | 4488·49 | 1 | — | |
| 4501·45 | 8 | 4 | 4501·45 | 5 | Ti | |
| 4529·69 | 3 | trace | 4529·66 | 1 | — | |
| | | | 4529·73 | 1 | — | [13] |
| 4534·14 | 5 | 2 | 4534·14 | 6 | Ti-Co | [14] |
| 4549·81 | 8 | 4 | 4549·81 | 6 | Ti-Co | [15] |
| 4563·94 | 7 | 3 | 4563·94 | 4 | Ti | |
| 4572·16 | 9 | 4 | 4572·16 | 6 | Ti | |
| 4590·13 | 3 | 1—2 | 4590·13 | 3 | — | |
| 4657·38 | 2 | trace | 4657·38 | 2 | Ti? | |
| 4764·10 | 1 | 0 | 4764·11 | 4 | Ti-Ni | [16] |

1. Ti probably true origin.
2. Ti probably true origin.
3. Ti line and solar line exactly coincident.
4. Solar line possibly only partially due to Ti.
5. Solar line exactly coincident with *p* Ti line.
6. This *p* Ti line is apparently exactly coincident with the Fe line, and solar line is probably compounded of both.
7. Solar line doubtless due to Ti.
8. Solar line doubtless due to Ti.

## Notes on *p* Ti-Solar Lines.

(The figures at the head of each note refer to Rowland's solar lines.)

[1.] 3900·68 (5), Ti-Fe-Zr.—The titanium line involved in the solar line is one of the very strongest in the spark spectrum. The iron line is only a weak one, and, in the light of other adjacent iron lines of equal intensity, would of itself only produce a solar line of intensity 2 or 3. In apportioning the weights to the various elements which possibly take part in the formation of the solar line, zirconium can be almost ignored. There are many far stronger lines of zirconium than the one in question, which are not represented in the sun at all. It would appear, then, that the solar line 3900·68 is really made up of the *p* Ti and Fe lines in about equal proportions.

[2.] 3913·61 (5), Ti-Fe.—It is very doubtful whether Fe takes any part in the production of this solar line. There is no such iron line recorded by either Kayser and Runge or Exner and Haschek, and there is no trace of a line in any of the Kensington photographs. The titanium line is a very prominent one in the spark spectrum, and quite capable of producing the solar line of itself.

[3.] 4053·98 (3), Fe-Ti.—The iron line is an extremely faint one, while the titanium line is well marked. The solar line is probably a composite one, but more attributable to titanium than iron.

[4.] 4055·19 (3), Ti-Fe.—The iron and titanium lines are coincident, and about equally strong. Solar line probably due to both.

[5.] 4163·82 (4), Ti-Cr.—Both the titanium and chromium lines are well marked in their respective spectra. The former seems to be slightly less refrangible than the other. The solar line is probably a very close double, and due to both Ti and Cr.

[6.] 4172·07 (2), Ti-Fe.—The iron line is extremely weak, while the *p* Ti line is one of the strongest in the spectrum. The solar line is probably due chiefly to Ti.

[7.] 4173·71 (1); no origin by Rowland.—The mean result of two measurements of this enhanced titanium line gives λ 4173·71. Its identity with the solar line is therefore well established.

[8.] 4184·47 (2); no origin by Rowland.—The published wave-length of this enhanced titanium line was 4184·40. A re-estimation from a later grating photograph gives as a resulting wave-length 4184·49. There is little doubt of its identity with the solar line 4184·47.

[9.] 4330·87 (2), Ti-Ni.—The nickel line is an exceedingly weak one, and it is doubtful whether the solar line is partially produced by it. Rowland, in a footnote in his 'Tables of Solar Wave-Lengths,' says: "This is a weak, hazy, nickel line. It is on the red edge of the solar line, and the Ti line is nearer the centre."

[10.] 4374·98 (0), Zr.—The published wave-length of the enhanced titanium line was 4374·90. A re-estimation from a better photograph gives 4374·99. It is probably identical with the weak solar line 4374·98, which Rowland ascribes to Zr.

[11.] 4399·94 (3), Ti-Cr.—The chromium line, although apparently coincident with the titanium and solar lines, is a very weak one. On the other hand, the titanium line is quite well marked. The solar line is therefore probably due chiefly to titanium.

[12.] 4411·24 (1), Cr.—Re-measurement of the proto-titanium line gives λ 4411·24. It is apparently coincident both with the chromium and solar lines. The chromium line is a weak one, whereas the titanium line is well marked, and there is little doubt that the solar line is partially, if not chiefly, due to titanium.

[13.] 4529·66 (1)<br>4529·73 (1) } No origin by Rowland.—The published wave-length of the enhanced titanium line was 4529·60. Re-measurement from the latest grating photograph gives λ 4529·69. It is doubtful which of the two solar lines, 4529·66

4529·73, the titanium line represents. It is quite possible that the latter is a very close double, and may account for both solar lines.

[14.] 4534·14 (6), Ti-Co.—Both the titanium and cobalt lines are well marked in their respective spectra, and there is little doubt that the solar line is compounded of the two.

[15.] 4549·81 (6), Ti-Co.—The titanium and cobalt lines are apparently coincident, and as each is a strong line in its own spectrum, the solar line is probably compounded of both in about equal proportion.

[16.] 4764·11 (4), Ti-Ni.—The enhanced titanium line is a very weak one, and the probability is that Ni is the chief origin of the solar line.

## Iron.

| λ. Enhanced Fe lines. | Intensity. | | Fraunhoferic lines (Rowland). | | | Notes appended. |
|---|---|---|---|---|---|---|
| | Spark, max. 10. | Arc. max. 10. | λ. | Int., max. 1000. | Origin. | |
| 3839·78 | 2—3 | 0 | 3839·76 | 2 | Fe | |
| 3846·55 | 2—3 | 1 | 3846·55 | 2 | Fe | |
| 3863·87 | 3 | 1—2 | 3863·89 | 3 | Fe | |
| 3871·86 | 4 | 1—2 | 3871·96 | 2 | Fe | |
| 3906·14 | 1 | 0 | 3906·17 | 00 | — | |
| 3935·92 | 5 | 4 | 3935·97 | 2 | Fe | |
| 3939·28 | 1—2 | 0 | 3939·29 | 0 | — | |
| 4002·77 | 1—2 | trace | 4002·81 | 0 | — | |
| 4048·93 | 3—4 | 2 | 4048·91 | 5 | Mn-Cr | 1 |
| 4055·73 | 3 | 2 | 4055·70 | 6 | Mn | 2 |
| 4173·61 | 3 | 1—2 | 4173·62 | 3 | — | |
| 4179·05 | 3—4 | trace | 4179·03 | 3 | — | |
| 4233·32 | 4—5 | 0 | 4233·33 | 4 | Mn-Fe | [1] |
| 4296·72 | 2 | 0 | 4296·74 | 3 | — | |
| 4302·35 | 2—3 | 2 | 4302·35 | 2 | Fe | |
| 4303·34 | 3—4 | 0 | 4303·34 | 2 | — | |
| 4351·93 | 5 | 0 | 4351·93 | 5 | Cr | [2] |
| 4385·55 | 3—4 | trace | 4385·55 | 2 | — | |
| 4451·75 | 3 | 2 | 4451·75 | 3 | Mn | 3 |
| 4462·30 | 2 | 0 | — | — | — | 4 |
| 4489·35 | 1 | 0 | 4489·35 | 2 | — | |
| 4491·57 | 2 | 0 | 4491·57 | 2 | — | |
| 4508·46 | 5 | trace | 4508·46 | 4 | Fe? | |
| 4515·51 | 4 | trace | 4515·51 | 3 | — | |
| 4520·40 | 3 | 1 | 4520·40 | 3 | Fe? | |
| 4522·77 | 6 | 2 | 4522·81 | 0 | — | 5 |
| 4541·46 | 3 | 1 | 4541·48 | 0 | — | |
| 4549·64 | 7 | 1 | 4549·64 | 2 | Fe | |
| 4556·09 | 5 | 0 | 4556·06 | 3 | — | |
| 4576·51 | | 0 | 4576·51 | 2 | — | |
| 4584·02 | 8 | 1 | 4584·02 | 4 | Fe | |
| 4629·51 | 4 | 0 | 4629·52 | 6 | Ti-Co | [3] |
| 4635·50 | 3 | 0 | 4635·49 | 0 | — | |
| 4924·11 | 8 | 0 | 4924·11 | 5 | Fe | |
| 5018·63 | 7 | 1 | 5018·63 | 4 | Fe | |
| 5169·07 } | 6 | 2 { | 5169·07 | 3 | Fe | |
| 5169·22 } | | | 5169·22 | 4 | Fe | |
| 5276·17 | 2 | 0 | 5276·17 | 3 | Fe? | |
| 5316·79 | 3 | 0 | 5316·79 | 4 | Fe | |

1. Probably partly due to the enhanced Fe line, in addition to Mn and Cr.
2. Solar line probably due partly to *p* Fe. K and R's λ 4055·63 (4).
3. Solar line probably compounded of the *p* Fe and Mn lines.
4. The *p* Fe line is apparently slightly more refrangible than solar line 4462·37.
5. This *p* Fe line is probably identical with Rowland's solar line 4522·81 rather than with 4522·69, to which he gives a Fe? origin.

## Notes on Certain *p* Fe-Solar Lines.

[1.] λ 4233·33 (4).—This solar line was ascribed by Rowland to Mn-Fe in his "Preliminary Table of Solar Wave-lengths." In the revised table* the Fe origin is discarded and the sole origin given as Mn. There appears to be, however, no evidence for the line being due to manganese. There is no trace whatever of a line in this position in any of the Kensington photographs of the manganese spectrum, and no such line is given by Hasselberg† in his comprehensive list of manganese arc lines. Although the arc line of iron at the corresponding wave-length is exceedingly weak—in many photographs it does not occur at all—there is no doubt about there being a prominent line in the spark spectrum. The solar line in question is probably due solely to iron, and is the counterpart of the enhanced line of that metal. In α Cygni the line 4233·33 is quite an outstanding line and one of the very strongest in the spectrum.

[2.] 4351·93 (5), Cr.—This solar line is ascribed by Rowland solely to Cr. Although the chromium line is a moderately strong one, it is scarcely likely that its solar equivalent would be as strong as that of the chromium line 4289·89, one of the very strongest lines in the spectrum of that element. The two solar lines mentioned being, however, of the same intensity, in all probability that at λ 4351·93 is partially due to some other element. The strongly enhanced Fe line 4351·93 is apparently exactly coincident with the Cr line, and as other similarly enhanced Fe lines occur amongst the Fraunhoferic lines, it is probable that the solar line in question is compounded of the iron and chromium lines.

In α Cygni there is a corresponding well-marked line which, in the light of the complete absence from the stellar spectrum of chromium arc lines, can only be attributed to proto-iron. This is the more likely, as the other enhanced lines of iron are so prominent in the α Cygni spectrum.

This line in stellar spectra has been attributed by Scheiner to the magnesium arc line 4352·08, and on its behaviour with respect to the stellar representative of the characteristic spark line of magnesium 4481·3, he has based conclusions‡ on the relative temperatures of the absorbing atmospheres of various stars. Such conclusions are not trustworthy, as the origin of the line is obviously not the same in all stellar spectra. In stars of the solar type the line is probably of a complex origin, Cr 4351·93, Mg 4352·08, and *p* Fe 4351·93, all being involved. In higher temperatures stars like α Cygni, Sirius, and Rigel there is abundant evidence in favour of a proto-Fe origin and little or none for either chromium or magnesium. Thus, other lines of Cr and Mg, which are similar in intensity and behaviour in their respective spectra to those mentioned above, are all unrepresented in these stellar spectra, whereas all the enhanced Fe lines of similar intensity and behaviour to the line 4351·93 are strongly represented in the same stellar spectra.

[3.] 4629·52 (6), Ti-Co.—It is doubtful whether the Ti and Co lines are collectively strong enough to account for the intensity of the solar line. The equally strong Co line 4663·59 only furnishes a solar line of intensity 0, and the stronger

* 'Ast. Phys. Jour.,' vol. 6, p. 384, 1897.

† 'Kongl. Sv. Vet. Akademiens Handlingar,' Bd. 30, No. 2.

‡ 'Ast. and Ast. Phys.,' vol. 13, p. 569.

Ti line 4623·28 corresponds to a solar line of intensity 2. It is scarcely likely, then, that the superposition of the Ti and Co lines at 4629·60 would produce a solar line of intensity 6. The proto-iron line at the same wave-length probably supplies the deficiency in intensity. The enhanced line of iron 4515·51, which is of about equal prominence as 4629·60, has an equivalent solar line of intensity 3, and if the *p* Fe line 4629·60 of itself produces a similar solar line, then the intensity 6 of the solar 4629·60 could be easily accounted for. In fact, it is quite probable that the solar line in question is built up of the lines at the same wave-length belonging to Ti, Co, and *p* Fe, and that the proto-iron line has, if anything, the greatest share in its production.

There is a fairly good corresponding line in the chromospheric spectrum, and, in the publication of eclipse results by various observers, the origin of the line is invariably given as Ti-Co, presumably because they have established its identity with the Fraunhoferic line and accepted Rowland's origin as a correct and sufficient one. In the chromosphere it is probably chiefly due to *p* Fe, as the ordinary Ti and Co lines are there only weak, while the enhanced iron lines are well marked. There is also a corresponding line in the spectrum of *α* Cygni. Here, however, the origin is evidently proto-iron only, as the arc lines of cobalt and titanium are entirely missing from the stellar spectrum; whereas nearly all the proto-iron lines are well seen.

## Chromium.

| λ. Enhanced Cr lines. | Intensity. | | Fraunhoferic lines (Rowland). | | Rowland's origin. | Notes appended. |
|---|---|---|---|---|---|---|
| | Spark, max. 10. | Arc, max. 10. | λ. | Int., max. 1000. | | |
| 3814·07 | 2 | 0 | 3814·07 | 1 | — | |
| 3865·67 | 7 | <1 | 3865·67 | 7 | Fe-Cr | 1 |
| 3866·69 | 1—2 | 0 | — | — | — | |
| 3905·66 | 6 | 0 | 3905·66 | 12 | Si | 2 |
| 3979·66 | 5—6 | 0 | 3979·66 | 4 | Co | [1] |
| 4003·55 | 4 | 0 | — | — | — | |
| 4012·63 | 6—7 | 2 | 4012·63 | 0 | Cr | |
| 4038·10 | 4—5 | 0 | — | — | — | |
| 4052·10 | 3 | 0 | 4052·18 | 0 | — | |
| 4058·92 | 5 | 3—4 | 4058·92 | 3 | Fe-Cr | 3 |
| 4071·07 | 4 | 0 | 4071·14 | 00 | — | |
| 4082·50 | 2—3 | 0 | 4082·43 | 0 | — | |
| 4111·25 | 4 | 0 | — | — | — | |
| 4145·91 | 6 | 0 | 4145·91 | 1 | — | |
| 4225·02 | 4 | 0 | 4225·02 | 2 | — | |
| 4233·50 | 2—3 | 0 | — | — | — | |
| 4242·54 | 6—7 | 0 | 4242·54 | 2 | — | |
| 4252·80 | 3 | 0 | 4252·79 | 0 | — | |
| 4262·15 | 5 | 0 | 4262·09 | 1 | — | 4 |
| | | | 4262·14 | 1 | — | |
| 4269·41 | 2 | 0 | 4269·45 | 0 | — | |
| 4284·38 | 3—4 | 0 | 4284·38 | 2 | — | 5 |
| 4307·20 | 2—3 | 0 | — | — | — | |
| 4555·16 | 5—6 | 1 | 4555·16 | 2 | — | |
| 4558·83 | 10 | 1 | 4558·83 | 3 | Cr? | |
| 4588·38 | 10 | 1 | 4588·38 | 3 | — | |

Chromium—*continued.*

| λ. Enhanced Cr lines. | Intensity. | | Fraunhoferic lines (Rowland). | | Rowland's origin. | Notes appended. |
|---|---|---|---|---|---|---|
| | Spark, max. 10. | Arc, max. 10. | λ. | Int., max. 1000. | | |
| 4592·23 | 4—5 | 0 | 4592·23 | 1 | Cr | |
| 4616·80 | 3—4 | 0 | 4616·80 | 1 | — | |
| 4618·97 | 8 | 0 | 4618·97 | 4 | Fe | [2] |
| 4634·25 | 8 | 0 | 4634·25 | 2 | — | |
| 4812·72 | 2—3 | 0 | — | — | — | |
| 4824·33 | 8 | 0 | 4824·33 | 3 | Fe | 6 |
| 4836·40 | 2—3 | 0 | 4836·42 | 0 | — | |
| 4848·44 | 6 | 0 | 4848·44 | 2 | — | |
| 4856·37 | 1 | 0 | — | — | — | |
| 4864·51 | 5 | 0 | 4864·51 | 1 | — | |
| 4876·59 | 5 | 0 | 4876·59 | 1 | — | |

1. Fe line and *p* Cr lines apparently coincident. Solar line probably compounded of both.

2. *p* Cr and Si lines exactly coincident. Solar line probably due to both, but mostly to Si.

3. Solar line probably due more to *p* Cr than Fe.

4. *p* Cr line possibly double.

5. Solar line possibly due partly to some other element.

6. Solar line probably compounded of Fe and *p* Cr lines.

## Notes on Certain *p* Cr-Solar Lines.

[1.] λ 3979·66, Co (4).—This enhanced line of chromium is apparently coincident with a cobalt line, and also with the solar line λ 3979·664, to which Rowland assigns a cobalt origin. As the adjacent cobalt line 3958·07 is quite as strong as 3979·66, and only furnishes a solar line of intensity 2, it is not probable that the solar line corresponding to 3979·66 would be of intensity 4, unless a line of some other element were involved. It is very probable that the solar line in question is compounded of the *p* Cr and Co lines.

[2.] λ 4618·97, Fe (4).—This strongly enhanced Cr line is apparently coincident with the solar line 4618·97 (intensity 4), Rowland's origin for which is Fe. The nearest line of iron to this in Kayser and Runge's list is 4618·88 (2). Assuming that this is identical in position with the solar line, its intensity is far too low to account for the solar intensity. The closely adjacent iron line 4619·40, which is of intensity 6, gives a solar line of intensity 3, so that it is very improbable that the far weaker iron line 4618·21 will produce a solar line of intensity 4. There is little doubt that the solar line 4618·97 is chiefly accounted for by the strongly enhanced chromium line, but the iron line at the same position probably adds slightly to the solar intensity.

## Fraunhoferic Lines due to *p* Ti, *p* Fe, or *p* Cr.

The following table contains the Fraunhoferic lines which are, as a result of the present discussion, considered to be due, either wholly or partially, to enhanced lines of titanium, iron, or chromium. Rowland's wave-lengths have been adopted with the modification that the last figure in the decimals has been dropped, and the numbers given to the nearest second decimal. In such an inquiry as the present one, this can be done without affecting the validity of the results. In the first place, the spark lines are generally of a wider and hazier nature than the arc lines, and consequently their wave-lengths cannot be estimated to as great a degree of accuracy. Again, the conclusions as to the identity of the solar and enhanced lines are not based on one or two coincidences only, but on the apparent agreement of a whole series of lines for each element.

It will be seen that some forty-two lines which were unorigined by Rowland are here attributed to proto-titanium, proto-iron, or proto-chromium. Compared with the host of lines in Rowland's tables this may seem a very insignificant number, but the importance of establishing their origins does not lie in their number, but in the fact that they are lines of a special nature, and just those metallic lines which are prevalent in the spectra of the higher temperature stars, such as $\alpha$ Cygni and Sirius, to the exclusion of the great majority of the other solar lines.

The enhanced lines have previously been identified with stellar lines, which in such stars as $\alpha$ Cygni, Sirius, and Rigel are of a more isolated nature than in the solar spectrum, and if the same lines can be established as occurring in the solar spectrum, it at once standardises the wave-lengths of many stellar lines, and will thus be of importance in any stellar inquiry in which it is necessary to have accurate wave-lengths for the spectral lines.

In some cases it has been found that there is no justification for the origin given by Rowland. These, however, are very few, and are indicated in the notes appended.

In others, Rowland's origin does not appear to be a sufficient one, that is, the intensity of the solar lines cannot be adequately accounted for by the lines of the elements to which he ascribes them. In such cases it is probable that the solar lines are due partly to the arc lines of the elements quoted by Rowland and partly to the enhanced lines of either Fe, Ti, or Cr, which occur at or very near the same wave-lengths.

A glance at the table will show that for many lines the same element is given in the two columns for origins, the Kensington origin having the prefix "p." This simply means that there is an enhanced line of that particular element at the given wave-length, which is not

entirely absent from the arc spectrum, and that Rowland has identified the solar line with the arc equivalent of the enhanced line. Seeing, however, that most of these lines occur in stellar spectra, where hosts of stronger arc lines are missing; it will, perhaps, be more appropriate to designate them as of a proto-metallic origin even in the sun.

Solar Lines due either wholly or partially to Enhanced Lines of Ti, Fe, or Cr.

| Fraunhoferic lines (Rowland). | | | Probable origin (Kensington). | Notes appended. |
|---|---|---|---|---|
| λ. | Int., max. 1000. | Origin. | | |
| 3813·54 | 2 | C | *p* Ti | |
| 3814·74 | 3 | C | *p* Ti | |
| 3836·23 | 2 | — | *p* Ti | |
| 3839·76 | 2 | Fe | *p* Fe | |
| 3846·55 | 2 | Fe | *p* Fe | |
| 3863·89 | 3 | Fe | *p* Fe | |
| 3865·67 | 7 | Fe-C | Fe-*p* Cr | |
| 3871·96 | 2 | Fe | *p* Fe | |
| 3900·68 | 5 | Ti-Fe-Zr | *p* Ti-Fe | 1 |
| 3905·66 | 12 | Si | Si *p* Cr | |
| 3906·17 | 00 | — | *p* Fe | |
| 3913·61 | 5 | Ti-Fe | *p* Ti | 2 |
| 3932·16 | 1 | Ti | *p* Ti | |
| 3935·97 | 2 | Fe | *p* Fe | |
| 3939·29 | 0 | — | *p* Fe | |
| 3979·66 | 4 | Co | Co *p* Cr | |
| 3987·76 | 2 | Ti ? | *p* Ti | |
| 4002·81 | 0 | — | *p* Fe | |
| 4012·54 | 4 | Ti | *p* Ti | |
| 4012·63 | 0 | Cr | *p* Cr | |
| 4025·29 | 3 | Ti | *p* Ti | |
| 4028·50 | 4 | Ti | *p* Ti | |
| 4048·91 | 5 | Mn-Cr | Mn-Cr-*p* Fe | 3 |
| 4053·98 | 3 | Fe-Ti | *p* Ti-Fe | |
| 4055·19 | 3 | Ti-Fe | *p* Ti, Fe | |
| 4055·70 | 6 | Mn | Mn *p* Fe | 4 |
| 4058·92 | 3 | Fe-Cr | Cr *p* Fe | 5 |
| 4145·91 | 1 | — | *p* Cr | |
| 4161·68 | 4 | — | *p* Ti | 6 |
| 4163·82 | 4 | Ti-Cr | *p* Ti, Cr | |
| 4172·07 | 2 | Ti-Fe | *p* Ti | 7 |
| 4173·62 | 3 | — | *p* Fe | |
| 4173·71 | 3 | — | *p* Ti | |
| 4174·24 | 0 | — | *p* Ti | |
| 4179·03 | 3 | — | *p* Fe | |
| 4184·47 | 2 | — | *p* Ti | |
| 4225·02 | 2 | — | *p* Cr | |
| 4227·47 | 1 | — | *p* Ti | |
| 4233·33 | 4 | Mn | *p* Fe | 8 |
| 4242·54 | 2 | — | *p* Cr | |
| 4252·79 | 0 | — | *p* Cr | |
| 4262·09 | 1 | — | *p* Cr | 9 |
| 4262·14 | 1 | — | | |

Solar Lines due to Enhanced Lines of Ti, Fe, or Cr—*continued*.

| Fraunhoferic lines (Rowland). | | | Probable origin (Kensington). | Notes appended. |
|---|---|---|---|---|
| λ. | Int., max. 1000. | Origin. | | |
| 4284·38 | 2 | — | *p* Cr | |
| 4290·38 | 2 | Ti | *p* Ti | |
| 4294·20 | 2 | Ti | *p* Ti | |
| 4296·74 | 3 | — | *p* Fe | |
| 4300·21 | 3 | Ti | *p* Ti | |
| 4302·09 | 2 | Ti | *p* Ti | |
| 4302·35 | 2 | Fe | *p* Fe | |
| 4303·34 | 2 | — | *p* Fe | |
| 4308·08 | 6 | Fe | Fe *p* Ti | |
| 4313·03 | 3 | Ti | *p* Ti | |
| 4315·14 | 3 | Ti | *p* Ti | |
| 4316·96 | 1 | Ti? | *p* Ti | |
| 4321·12 | 2 | — | *p* Ti | |
| 4330·41 | 1 | — | *p* Ti | |
| 4330·87 | 2 | Ti-Ni | *p* Ti | 10 |
| 4338·08 | 4 | Ti | *p* Ti | |
| 4341·53 | 2 | Ti? | *p* Ti | |
| 4344·45 | 2 | Ti | *p* Ti | |
| 4351·00 | 1 | Ti | *p* Ti | |
| 4351·93 | 5 | Cr | Cr *p* Fe | |
| 4367·84 | 2 | Ti | *p* Ti | |
| 4374·98 | 0 | Zr | *p* Ti | 11 |
| 4385·55 | 2 | — | *p* Fe | |
| 4387·01 | 1 | Ti? | *p* Ti | |
| 4391·19 | 1 | Ti | *p* Ti | |
| 4395·20 | 3 | Ti | *p* Ti | |
| 4396·01 | 1 | Ti | *p* Ti | |
| 4399·94 | 3 | Ti-Cr | *p* Ti Cr | 12 |
| 4411·24 | 1 | Cr | *p* Ti Cr | |
| 4417·88 | 3 | Ti | *p* Ti | |
| 4421·93 | 00 | Ti | *p* Ti | |
| 4443·98 | 5 | Ti | *p* Ti | |
| 4450·65 | 2 | Ti? | *p* Ti | |
| 4451·75 | 3 | Mn | Mn *p* Fe | |
| 4464·62 | 2 | Ti? | *p* Ti | |
| 4468·66 | 5 | Ti | *p* Ti | |
| 4488·49 | 1 | — | *p* Ti | |
| 4489·35 | 2 | — | *p* Fe | |
| 4491·57 | 2 | — | *p* Fe | |
| 4501·45 | 5 | Ti | *p* Ti | |
| 4508·46 | 4 | Fe? | *p* Fe | |
| 4515·51 | 3 | — | *p* Fe | |
| 4520·40 | 3 | Fe? | *p* Fe | |
| 4522·81 | 3 | — | *p* Fe | |
| 4529·66 | 1 | — | *p* Ti | 13 |
| 4529·73 | 1 | — | | |
| 4534·14 | 6 | Ti-Co | *p* Ti-Co | |
| 4541·48 | 0 | — | *p* Fe | |
| 4549·64 | 2 | Fe | *p* Fe | |
| 4549·81 | 6 | Ti-Co | *p* Ti, Co | |
| 4555·16 | 2 | — | *p* Cr | |
| 4556·06 | 3 | — | *p* Fe | |
| 4558·83 | 3 | Cr? | *p* Cr | |

Solar Lines due to Enhanced Lines of Ti, Fe, and Cr—*continued.*

| Fraunhoferic lines (Rowland). | | | Probable origin (Kensington). | Notes appended. |
|---|---|---|---|---|
| λ. | Int., max. 1000. | Origin. | | |
| 4563·94 | 4 | Ti | *p* Ti | |
| 4572·16 | 6 | Ti | *p* Ti | |
| 4576·51 | 2 | — | *p* Fe | |
| 4584·02 | 4 | Fe | *p* Fe | |
| 4588·38 | 3 | — | *p* Cr | |
| 4590·13 | 3 | — | *p* Ti | |
| 4592·25 | 1 | Cr | *p* Cr | |
| 4616·81 | 1 | — | *p* Cr | |
| 4618·97 | 4 | Fe | *p* Cr-Fe | 14 |
| 4629·52 | 6 | Ti Co | *p* Fe, Ti, Co | |
| 4634·25 | 2 | — | *p* Cr | |
| 4635·49 | 0 | — | *p* Fe | |
| 4657·38 | 2 | Ti? | *p* Ti | |
| 4824·33 | 3 | Fe | Fe *p* Cr | |
| 4836·42 | 0 | — | *p* Cr | |
| 4848·44 | 2 | — | *p* Cr | |
| 4864·51 | 1 | — | *p* Cr | |
| 4876·59 | 1 | — | *p* Cr | |

1. Zr negligible.
2. No evidence for Fe origin.
3. Chiefly due to Mn.
4. Chiefly due to Mn.
5. Chiefly due to *p* Cr.
6. Possibly due partially to some other element.
7. No evidence for Fe origin.
8. No evidence for Mn.
9. Doubtful which is really due to *p* Cr.
10. Evidence for Ni doubtful.
11. No evidence for Zr.
12. Chiefly due to *p* Ti.
13. Doubtful which is really due to *p* Ti.
14. Chiefly due to *p* Cr.

## General Conclusions.

As a general summary of the results of the foregoing analysis it may be stated :—

1. The enhanced lines of titanium and iron are practically all represented in the Fraunhoferic spectrum, but in some cases the corresponding solar lines are compound, and only partly due to one or other of these metals.

2. The corresponding solar lines are, generally speaking, comparatively weak ones.

3. The majority of the chromium enhanced lines occur in the solar spectrum, though some appear to be missing.

4. Some of the Fraunhoferic lines correspond to metallic lines special to the spark spectrum, and lacking in the arc, and probably for this reason they were left unorigined by Rowland.

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APPENDIX TO VOL. LXV.

[*From Proceedings of the Royal Society, Vol. LXXIV.*]

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"The Arc Spectrum of Scandium and its Relation to Celestial Spectra." By Sir NORMAN LOCKYER, K.C.B., LL.D., Sc.D. F.R.S., and F. E. BAXANDALL, A.R.C.Sc. Received January 3, —Read February 9, 1905.

Very little has been published regarding the spectrum of this rare element. The records of Thalen,* and Exner and Haschek,† are the only ones previously given, the former observer confining his attention to the spark spectrum, whereas Exner and Haschek have recorded the lines under both arc and spark conditions. In the latter lists, however, no lines are given in the region less refrangible than $\lambda$ 4744·0. Rowland, in his "Tables of Solar Wave-lengths," certainly ascribes a small number of solar lines to scandium, but, of course, no indication is there given as to the relation of these lines to others which occur in the scandium spectrum, either in regard to number or intensity. In connection with the work at Kensington on stellar and other celestial spectra, it has been found that in some types of spectra scandium is conspicuously represented by some of its lines, in fact,

* 'Öfversigt af Kongl. Vetensk. Akad. Forhandl.,' vol. 38, No. 6, p. 13.

† 'Wellenlängen-Tabellen für Spektralanalytische Untersuchungen auf Grund der Ultravioletten Funkenspektren und Bogenspektren der Elemente,' Leipzig und Wien, Franz-Deuticke, 1902.

amongst the rarer elements it apparently stands by itself from this point of view. This prominence of scandium lines in some stellar spectra, and particularly in the chromospheric spectrum, makes it desirable to give as complete a record of the lines as possible, and also to analyse them in relation to their appearance or non-appearance in extra-terrestrial spectra.

Some time ago Sir William Crookes was good enough to send a sample of scandium oxalate, and very good photographs of the arc spectrum have been obtained with a larger Rowland concave grating, having a ruled surface of $5\frac{3}{4} \times 2$ inches ($14\frac{1}{2} \times 5$ cm.), and a radius of 21 feet 6 inches. The scale of the photographs is such that the distance between K and D is $30\frac{1}{4}$ inches, or 77 cm. This is equivalent to 2·6 tenth-metres per millimetre. The scandium oxalate was admittedly impure, and for the purpose of eliminating lines due to impurities, the spectrum has been directly compared with the spectra of all the chemical elements available at Kensington, which were photographed under identical instrumental conditions. The chief sources of impurity were found to be cerium, thorium and ytterbium. The lines of the first two elements were easily eliminated by comparison with the Kensington photographs of their respective arc spectra. In the case of ytterbium it was a more difficult matter, as this is one of the elements not investigated at Kensington. The elimination of its lines has, however, been accomplished as far as possible, by ascertaining whether there were lines in the scandium photograph in the position of the stronger lines of ytterbium as recorded by Thalen,* and Exner and Haschek.† If such were found to be the case, and the intensity in the scandium photographs such that the line was thought to be due to ytterbium, it was discarded from the list of scandium lines.

The fiducial lines used for the reduction of wave-lengths were the H and K lines of calcium (which occur as impurity lines in the scandium spectrum), and Rowland's solar-scandium lines 3907·62, 4020·55, 4082·59, 4247·00, 4314·25, 4400·56, 4670·59, 5672·05. The coincidence of these lines was first confirmed by a direct comparison of the Kensington photographs of the solar and scandium spectra. In addition to the foregoing, well-marked scandium lines were found to be exactly coincident with the isolated solar lines 5031·20, 5239·99, and 5527·03, for which Rowland had given no origin. The solar wave-lengths of these were adopted and used in the reduction of the wave-lengths of the remaining lines.

The table at the end of the paper gives the residuum of lines after

* 'Öfversigt k. Vetensk. Akad. Forhandl.' (1881).

† Wellenlängen-Tabellen für Spektralanalytische Untersuchungen auf Grund der Ultravioletten Bogenspektren der Elemente,' Leipzig und Wien, Franz-Deuticke. 1904.

the elimination of those due to other metals. There can be little doubt that the majority of the lines, except, perhaps, some of the very lowest intensity, really belong to scandium. Exner and Haschek's wave-lengths and intensities of the scandium arc lines are given for comparison.

*Scandium Lines in the Solar Spectrum.*

Rowland, in his "Tables of Solar Wave-lengths," ascribes a small number of lines to scandium, but a comparison of the Kensington photographs of the arc spectrum of this element with the solar spectrum shows that in addition to these there are other solar lines nearly certainly due to the same element. The table gives the solar lines which, by a careful comparison of the metallic and solar spectra, have been considered to correspond, without any doubt, with scandium lines. In addition to these, there is a considerable number which agree closely in position with weak solar lines, but of their identity there is, perhaps, some doubt. In some cases the solar lines are so weak that it is impossible to establish their identity with scandium lines by direct comparison of the two spectra, the only guide being the close agreement in wave-length, and the relative intensity of the metallic and solar lines. In other cases it is doubtful whether the metallic lines are strong enough to account for the solar lines. In the table these lines are denoted by an asterisk, and must be accepted only provisionally as "possible" scandium-solar lines.

The following analysis of the scandium lines, with reference to their intensities, and their appearance or non-appearance in the solar spectrum, will be of interest.

| Intensity (Sc. arc lines). | Total number of Sc. lines. | Number undoubtedly represented in solar spectrum. | Number possibly represented in solar spectrum. | Number apparently absent from solar spectrum. |
|---|---|---|---|---|
| 10 | 4 | 4 | — | — |
| 9 | 3 | 3 | — | — |
| 8 | 7 | 6 | 1 | — |
| 7 | 4 | 3 | 1 | — |
| 6 | 5 | 2 | 1 | 2 |
| 5 | 7 | 3 | 4 | — |
| 4 | 15 | 6 | 3 | 6 |
| 3 | 21 | — | 5 | 16 |
| 2 | 28 | — | 2 | 26 |
| 1 | 16 | — | — | 16 |

It will be seen that of the 23 lines of intensity 6 or greater, 18 occur in the solar spectrum, three others are doubtfully present, while

two appear to be lacking. Of the lines below intensity 6, the great majority are missing from the Fraunhoferic spectrum.

*Scandium Lines and the Chromospheric Spectrum.*

The scandium lines which occur in the chromospheric spectrum, though not so numerous as those in the solar spectrum, are of considerably greater prominence. The strongest line of scandium at λ 4247·00 is very well developed in the chromosphere, and is, as far as the metallic lines are concerned, inferior only to the lines of strontium and calcium. Although all the scandium lines represented in the chromosphere have high intensities in the scandium arc spectrum, there are a few others of equal prominence in the metallic spectrum which are either lacking or occur only as quite insignificant lines in the chromospheric spectrum.

Chromospheric Lines probably due either wholly or partially to Scandium.

| Chromospheric line. | | Scandium line. | | | Remarks. |
|---|---|---|---|---|---|
| λ. | Intensity. Max. 10. | λ. | Intensity. Arc. Max. 10. | Intensity. Spark. Max. 10. | |
| 4247·0 | 7 | 4247·00 | 10 | 10 | Due solely to scandium. |
| 4314·0 | 2 | 4314·25 | 9 | 8 | „ „ |
| 4321·2 | 5 | 4320·90 | 9 | 6 | Probably partially due to *p*Ti 4321·20. |
| 4374·9 | 7 | 4374·65 | 8 | 6 | Probably partially due to *p*Ti 4374·90. |
| 4399·9 | 5—6 | 4400·56 | 8 | 5 | Probably partially due to *p*Ti 4399·94. |
| 4670·8 | 3—4 | 4670·59 | 7 | 4 | Due solely to scandium. |
| 5031·2 | 2 | 5031·20 | 8 | 3 | „ „ |
| 5527·6 | 6 | 5527·03 | 10 | 7 | This chromospheric line is broad and is probably composed of the scandium line and the strong Mg spark line λ 5528·64 |

*Scandium Lines in Sun-Spot Spectra.*

Between F and D, the region over which the Kensington observations of sun-spot spectra extend, there are nine solar lines which have been found to be due to scandium, either wholly or partially. Of these, five

occur amongst the most widened lines observed during the last 24 years. Four of them, however, have only been recorded a few times. The remaining one, λ 5672·047, is a very persistent widened line and is nearly always greatly affected. It is, of course, quite possible that the solar line in question, although weak, may be a compound one, and that an additional chemical element is involved in its formation. No origin other than scandium has been suggested by Rowland, and no alternative origin has been found for it by reference to Kensington spectra of metals. It must, therefore, be accepted provisionally as being really due to scandium.

*Scandium Lines in Stellar Spectra.*

It is quite probable that, as the stronger scandium lines occur in the solar spectrum, they also appear in the spectra of stars resembling the sun, such as those of the Aldebarian and Arcturian types. The closeness of the lines in these stars with the dispersion usually employed on stellar spectra makes it difficult to establish definitely whether the scandium lines are really present. At the next higher stage (Polarian, *e.g.*, γ Cygni) those scandium lines previously given as occurring in the chromospheric spectrum—at least, those in the ordinary photographic region, say λ 3900 to λ 4700—occur as well marked lines, as has been shown in a previous paper.*

At the next higher stage Cygnian (α Cygni) the only line which can with certainty be ascribed to scandium is that at λ 4247·00, corresponding to the strongest line of the element. Its stellar intensity, has, however, decreased considerably from that of the Polarian stage. At the higher stages represented successively by Rigelian (β Orionis), Taurian (ζ Tauri), Crucian (γ Orionis), and Alnitamian (ζ Orionis) types scandium lines are entirely lacking.

The photographs of the metallic spectra involved in the discussion were taken by Mr. C. P. Butler, A.R.C.Sc.

* 'Phil. Trans.,' A, vol. 201, p. 205.

Arc Lines of Scandium.

* = Doubtfully identical with solar lines.

| Kensington. | | Exner and Haschek. | | Corresponding solar lines. | | Rowland's origin for solar lines. |
|---|---|---|---|---|---|---|
| λ. | Int. Max. 10. | λ. | Int. Max. 50. | λ. | Int. | |
| 3907·62 | 10 | 3907·69 | 30 | 3907·62 | 3 | Sc–Fe |
| 11·94 | 10 | 12·03 | 30 | 11·96 | 2 | Sc |
| | | 15·09 | 1 | | | |
| | | 18·36 | 1 | | | |
| | | 23·64 | 1 | | | |
| | | 33·59† | 6 | | | |
| | | 52·43 | 1 | | | |
| | | 89·18 | 1 | | | |
| * 96·75 | 5 | 96·79 | 15 | 96·68 | 00 | Sc |
| 4014·66 | 3 | 4014·68 | 6 | | | |
| 20·55 | 8 | 20·60 | 20 | 4020·55 | 1 | Sc |
| | | 23·36 | 1 | | | |
| 23·88 | 8 | 23·88 | 30 | 23·83 | 2 | Sc |
| | | 31·51 | 2 | | | |
| 34·35 | 2 | | | | | |
| 36·98 | 1 | | | | | |
| 43·97 | 2 | | | | | |
| 46·64 | 2 | | | | | |
| 47·97 | 4—5 | 47·98 | 10 | 47·96 | 0 | — |
| | | 50·09 | 2 | | | |
| | | 52·00 | 1 | | | |
| * 54·68 | 3 | 54·71 | 10 | 54·71 | 00 | Sc |
| | | 56·72 | 3 | | | |
| | | 67·15 | 2 | | | |
| | | 75·13 | 2 | | | |
| | | 78·70 | 2 | | | |
| 82·59 | 6 | 82·60 | 15 | 82·59 | 3 | Fe–Sc–Ti |
| | | 86·15 | 1 | | | |
| 86·67 | 2—3 | 86·80 | 3 | | | |
| 87·26 | 1 | 87·28 | 3 | | | |
| * 94·85 | 2—3 | 95·03 | 1 | 94·85 | 0 | — |
| 4106·02 | 2—3 | | | | | |
| 33·10 | 2 | 4133·10 | 4 | | | |
| * 40·42 | 2—3 | 40·42 | 5 | 4140·40 | 0 | — |
| 41·78 | 1 | | | | | |
| 52·50 | 3 | 52·51 | 8 | | | |
| 62·85 | 1 | | | | | |
| 63·77 | 1 | | | | | |
| 65·38 | 2—3 | 65·39 | 8 | | | |
| 71·47 | 1—2 | | | | | |
| 71·98 | 2—3 | 71·92 | 2 | | | |
| | | 4218·43 | 1 | | | |
| | | 19·90 | 1 | | | |
| 4224·32 | 1 | | | | | |
| | | 25·76 | 1 | | | |
| | | 32·13 | 1 | | | |

† Possibly masked in Kensington photograph by K line of Ca.

Arc Lines of Scandium—*continued.*

| Kensington. | | Exner and Haschek. | | Corresponding solar lines. | | Rowland's origin for solar lines. |
|---|---|---|---|---|---|---|
| λ. | Int. Max. 10. | λ. | Int. Max. 50. | λ. | Int. | |
| | | 4233·83 | 2 | | | |
| | | 37·96 | 1 | | | |
| 4238·25 | 2 | 38·21 | 3 | | | |
| | | 39·72 | 1 | | | |
| | | 46·27 | 1 | | | |
| 47·00 | 10 | 47·02 | 50 | 4247·00 | 5 | Sc |
| | | 51·22 | 1 | | | |
| | | 83·71 | 1 | | | |
| | | 86·71 | 1 | | | |
| * 94·91 | 4—5 | 94·94 | 5 | 94·94 | 2 | Zr |
| 4305·83 | 4—5 | 4305·89 | 8 | 4305·87 | 2 | — |
| 14·25 | 9 | 14·31 | 30 | 14·25 | 3 | Sc |
| 20·90 | 9 | 20·98 | 20 | 20·91 | 3 | Sc |
| 25·15 | 8 | 25·28 | 20 | 25·15 | 4 | Sc |
| 54·74 | 3—4 | 54·79 | 3 | 54·78 | 1 | — |
| | | 58·85 | 1 | | | |
| | | 59·25 | 1 | | | |
| 74·65 | 8 | 74·69 | 20 | 74·63 | 3 | Sc |
| 84·99 | 4 | 84·98 | 3 | 84·99 | 0 | Sc |
| | | 89·76 | 1 | | | |
| 4400·56 | 8 | 4400·63 | 20 | 4400·56 | 3 | Sc |
| 15·72 | 7 | 15·78 | 20 | 15·72 | 3 | — |
| * 20·82 | 1—2 | 20·84 | 1 | 20·83 | 00 | — |
| * 31·56 | 2—3 | 31·52 | 2 | 31·53 | 0 | — |
| | | 4542·74 | 1 | | | |
| | | 44·86 | 1 | | | |
| | | 57·45 | 1 | | | |
| *4563·40 | 2 | — | — | 4563·41 | 00 | — |
| | | 74·20 | 2 | | | |
| | | 4604·88 | 1 | | | |
| 4670·59 | 7 | 70·59 | 5 | 4670·59 | 2 | Sc |
| | | 4709·53 | 1 | | | |
| | | 29·43 | 2 | | | |
| *4729·39 | 3 | 29·40 | 1 | 4729·38 | 0000 | — |
| * 34·31 | 3—4 | 34·31 | 3 | 34·28 | 1 | Fe? |
| 37·88 | 4 | 37·86 | 3 | | | |
| * 41·24 | 5 | 41·23 | 4 | 41·26 | 1 | Fe? |
| * 44·04 | 6 | 44·01 | 5 | 44·01 | 000 | — |
| | | Exner and Haschek's record st ops here. | | | | |
| 4820·52 | 2—3 | | | | | |
| 37·27 | 2—3 | | | | | |
| 4937·29 | 2—3 | | | | | |
| 54·12 | 1—2 | | | | | |
| 80·49 | 1 | | | | | |
| 87·26 | 1—2 | | | | | |
| 92·06 | 1—2 | | | | | |
| 5009·68 | 2 | | | | | |
| 31·20 | 8 | — | — | 5031·20 | 3 | — |
| 64·35 | 2 | | | | | |
| 70·34 | 3—4 | | | | | |

Arc Lines of Scandium—*continued.*

| Kensington. | | Exner and Haschek. | | Corresponding solar lines. | | Rowland's origin for solar lines. |
|---|---|---|---|---|---|---|
| λ. | Int. Max. 10. | λ. | Int. Max. 50. | λ. | Int. | |
| 5075·85 | 1—2 | | | | | |
| 79·79 | 1 | | | | | |
| 81·68 | 6 | | | | | |
| 83·77 | 5 | | | | | |
| * 85·64 | 4 | — | — | 5085·67 | 0 | — |
| 87·06 | 3 | | | | | |
| 87·18 | 2 | | | | | |
| 89·95 | 2 | | | | | |
| 96·81 | 2 | | | | | |
| 99·28 | 3—4 | | | | | |
| 5101·21 | 2 | | | | | |
| 04·43 | 1 | | | | | |
| 05·60 | 2—3 | | | | | |
| 09·09 | 1 | | | | | |
| 10·85 | <1 | | | | | |
| 12·87 | 1 | | | | | |
| 16·73 | 2 | | | | | |
| 21·60 | 1 | | | | | |
| 31·14 | <1 | | | | | |
| 47·08 | 2 | | | | | |
| 48·28 | 2 | | | | | |
| 5239·99 | 5—6 | — | — | 5239·99 | 1 | — |
| 58·46 | 2—3 | | | | | |
| 69·65 | 1—2 | | | | | |
| 85·88 | 2 | | | | | |
| 5307·83 | 1 | | | | | |
| 18·41 | 2 | | | | | |
| 25·14 | 2 | | | | | |
| 28·05 | 1 | | | | | |
| 49·32 | 3 | | | | | |
| 56·14 | 3—4 | | | | | |
| 58·69 | 2—3 | | | | | |
| 89·89 | 1—2 | | | | | |
| 92·12 | 3 | | | | | |
| 5478·66 | 2 | | | | | |
| 82·18 | 4 | | | | | |
| * 84·81 | 3—4 | — | — | 5484·85 | 000 | — |
| 5514·40 | 4 | | | | | |
| * 20·70 | 4—5 | — | — | 5520·73 | 00 | — |
| 27·03 | 10 | — | — | 27·03 | 3 | — |
| 91·44 | 2 | | | | | |
| 5658·10 | 7 | — | — | 5658·10 | 2 | Y |
| 58·56 | 3—4 | — | — | 58·56 | 0 | — |
| 67·40 | 3—4 | — | — | 67·37 | 0 | — |
| 69·25 | 4 | — | — | 69·26 | 1 | — |
| 72·05 | 9 | — | — | 72·05 | 0 | Sc |
| 84·44 | 4 | — | — | 84·42 | 1 | — |
| * 87·07 | 8 | — | — | 87·06 | 000 | — |
| *5700·38 | 7 | — | — | 5700·40 | 00 | — |
| 11·98 | 6 | | | | | |
| 17·54 | 3 | | | | | |

"On the Stellar Line near λ 4686." By Sir Norman Lockyer, K.C.B., LL.D., Sc.D., F.R.S., and F. E. Baxandall, A.R.C.Sc. Received January 4,—Read February 9, 1905.

In the publication of the results derived from a study of the Kensington photographic spectra of the 1898 eclipse, it was stated* that a fairly prominent line recorded near λ 4686, for which no terrestrial origin could be found, agreed closely in position with a well-marked line of unknown origin in one of the Kensington photographs of the spectrum from a helium tube. In the helium photograph the position has been recently found from careful measures made on the lines 4120·97, 4388·10, 4713·25, and the line in question, and subsequent use of Hartmann's formula.

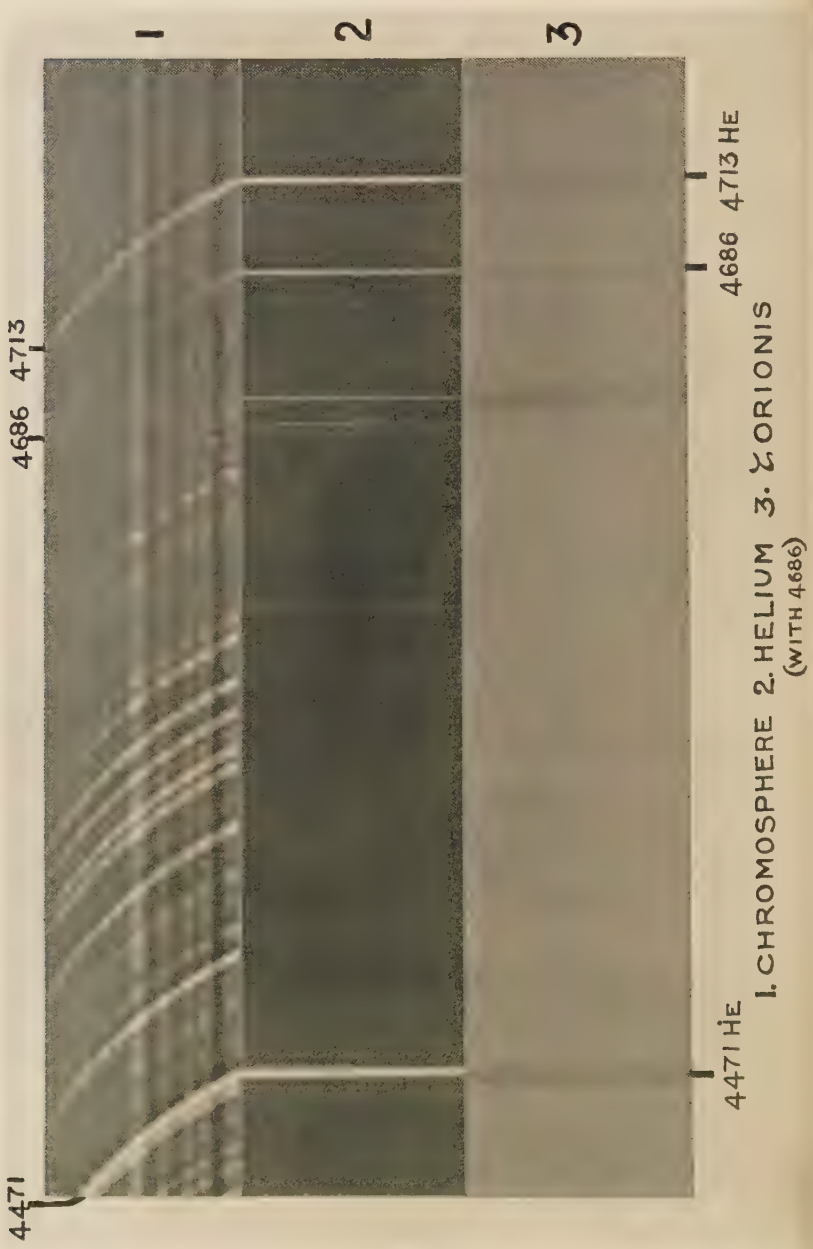
The resulting wave-length of the strange line was 4685·97. Similar measurements were made on the eclipse photographs, the fiducial lines used being 4508·5 (*p* Fe), 4584·0 (*p* Fe), and 4713·25 (He). The result gave 4685·90.

The two calculated wave-lengths so nearly agree that it is very probable the line is of identical origin in the two cases. The eclipse line is, moreover, of the same nature as the helium eclipse lines, long and sharply defined. It would therefore seem that the line is due to a gas which is associated in some way with helium. The line, however, only appears in one photograph of the helium spectrum, and whether this is due to the particular sample of helium used, or to some special condition of current which is conducive to the appearance of the strange line, it is impossible to say.

A line near the same position has been recorded by various spectroscopists in different celestial spectra. The following table contains the available records of the line in question :—

| Spectrum. | Observer. | λ. |
|---|---|---|
| Bright line stars | Campbell | 4688 |
| „ „ | Pickering | 4688 |
| „ „ | McClean | 4687·5 |
| Nebulæ | Campbell | 4687 |
| Orion stars | Pickering | 4685·4 |
| ε Orionis | Lockyer | 4687·0 |
| Trapezium star (Bond 628) | Keeler | 4685·4 |
| β Crucis | McClean | 4685·1 |
| Chromosphere | Evershed | 4685·7 |
| „ | Lockyer | 4687·0 |
| „ | Frost | 4685·7 |
| „ | Lord | 4686·3 |
| „ | Humphreys | 4685·4 |
| | Mean λ | 4686·4 |

* 'Phil. Trans.,' A, vol. 197, p. 202.




1. CHROMOSPHERE 2. HELIUM 3. ζ ORIONIS
(WITH 4686)

It will be seen that the mean wave-length is in fairly good accord with that of the unknown terrestrial line 4685·97. The line, however, in the nebular and bright-line-star spectra is broad and ill-defined, and the estimated wave-lengths are probably somewhat uncertain, and not to be depended on so much as those obtained from spectra in which the line is sharply defined. If in seeking the mean wave-length these probably less accurate wave-lengths be excluded, the result is 4685·9, which is in very close agreement with the position of the terrestrial line.

Rydberg has shown that the stellar line near 4686—associated with the new series discovered by Pickering in the spectrum of ζ Puppis—is probably the first line of the principal series furnished by hydrogen. His calculated wave-length value for the line is 4687·88,* which would appear to be about two tenth-metres in error, as the corresponding celestial line probably has, as is shown in the present note, a wave-length near 4685·9.

In the light of this evidence for the probable identity of the terrestrial and stellar lines, it seems desirable to institute further research on the spectrum of helium under varying electrical conditions with the object of possibly obtaining the terrestrial equivalents of the so-called new hydrogen series of ζ Puppis.

## DESCRIPTION OF PLATE.

The plate shows a comparison of the spectrum (region 4450 to 4750) of the chromosphere, the helium spectrum containing the line 4686, and that of ζ Orionis (Alnitamian). The identity of position of the helium lines, and 4686, with lines in the chromospheric and stellar spectra is clearly shown. The fainter lines in the helium spectrum are all due to oxygen.

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* 'Ast. Phys. Jour.,' vol. 6, p. 237.

"Note on the Spectrum of $\mu$ Centauri." By Sir Norman Lockyer, K.C.B., LL.D., Sc.D., F.R.S., and F. E. Baxandall, A.R.C.Sc. Received January 4,—Read February 9, 1905.

An investigation of Pickering's reproduction of this spectrum*—which apparently consists of the spectrum of an Orion star + bright hydrogen lines and certain other bright lines of minor intensity—suggested that the latter are radiation lines corresponding to some of the stronger absorption lines of $\alpha$ Cygni. These $\alpha$ Cygni lines have previously been attributed to the enhanced lines of certain metals, chiefly Fe, Ti, Cr, Mg, and Si.

A close investigation has now shown that nearly all the most marked bright lines in $\mu$ Centauri—other than those of hydrogen—occupy positions closely corresponding to those of the most conspicuous enhanced lines of iron. The wave-lengths of some of the bright $\mu$ Centauri lines are compared with those of the enhanced lines of iron and $\alpha$ Cygni lines in the table at the end of this note. The close agreement is very noticeable.

It is worth while, then, to analyse in detail Pickering's statement in his note† on the $\mu$ Centauri spectrum. He states: "Lines 4922·1 and 5015·8 are bright on the edge of greater wave-length." The lines whose wave-lengths he gives are the helium-Orion absorption lines. The only two enhanced iron lines in this region are at $\lambda\lambda$ 4924·11 and 5018·63, which occupy exactly the positions relatively to the helium lines which Pickering notes as being bright in the $\mu$ Centauri spectrum—that is, they border the helium lines on the edge of greater wave-length.

Again, he says: "The two most conspicuous (bright lines) are at wave-lengths 4232 and 4584 approximately." Two of the most marked lines in the $\alpha$ Cygni spectrum are at $\lambda\lambda$ 4233·25 and 4584·02, and these undoubtedly correspond to the two most conspicuous enhanced lines of iron between $H_\delta$ and $H_\beta$.

Again. "Line 4387·8 is bright on the edge of shorter wave-length." In $\alpha$ Cygni there is a well-marked line at $\lambda$ 4385·55, which agrees in position with another enhanced iron line.

Also: "A diffuse bright band appears on the side of shorter wave-length of the dark line 4531·4." There is a distinctive group of $\alpha$ Cygni—enhanced iron lines at $\lambda\lambda$ 4508·46, 4515·51, 4520·40, 4522·69, which, thrown together into an irresolvable group in $\mu$ Centauri, may well correspond to the diffuse line quoted by Pickering.

Further: "The dark line 4553·4 is superposed on a bright band."

* 'Annals Harv. Coll. Obs.,' vol. 28, Part II, Plate 1.

† 'Annals Harv. Coll. Obs.,' vol. 28, Part II, p. 178.

## Bright Lines in the Spectrum of μ Centauri.

| λ (μ Centauri). | Nature. | Probable origin. | λ of probable origin. | α Cygni. λ. | α Cygni. Intensity (Max. 10). | Remarks. |
|---|---|---|---|---|---|---|
| 4171·4 to 4181·4 | Bright and broad | *p* Fe | 4173·52 to 4178·95 | 4173·5 to 4179·0 | 6—7 to 6—7 | Mean position of Fe double 4176·2, that of the μ Centauri line 4176·4. |
| 4232·9 | Very bright and narrow | *p* Fe | 4233·25 | 4233·3 | 8 | |
| 4295·7 to 4303·1 | Bright but not well-marked | *p* Fe | 4296·65 to 4303·34 | 4296·7 to 4303·3 | 4 to 5 | Mean position of Fe double 4299·9, that of μ Centauri line 4299·4. |
| 4385·0 | Bright and narrow | *p* Fe | 4385·55 | 4385·5 | 5—6 | |
| 4508·9 | „ „ | *p* Fe | 4508·46 | 4508·5 | 5 | |
| 4515·1 | „ „ | *p* Fe | 4515·51 | 4515·5 | 5 | |
| 4518·6 to 4527·6 | Bright but irresolvable | ? *p* Fe + extra line | 4520·40 to 4522·69 | 4520·4 to 4522·7 | 4 to 5 | Mean position of *p* Fe double 4521·5, that of μ Centauri line 4523·3. |
| 4549·9 | Bright and narrow | *p* Fe | 4549·64 | 4549·8 | 7 | |
| 4556·3 | „ „ | *p* Fe | 4556·06 | 4556·1 | 5 | |
| 4584·6 | Very bright | *p* Fe | 4584·02 | 4584·0 | 7 | |

This bright band may very well correspond to the α Cygni enhanced iron lines 4549·64 and 4556·06 thrown together in the μ Centauri spectrum. It is possible, though, that the dark line 4553·4, quoted by Pickering, is only the dark interspace between the bright 4549·64 and 4556·06 lines.

It may be here remarked that among the brightest lines in the spectra of Novæ at their initial stages are lines agreeing in position with the most marked α Cygni and enhanced Fe lines, and in this way we trace a resemblance between the minor bright lines of μ Centauri and the most conspicuous bright lines—other than those of hydrogen —in the early spectra of Novæ.

Lines corresponding to these bright lines in μ Centauri also occur in the spectrum of γ Cassiopeiæ, but they are far less well-defined in the case of the latter star.

The wave-lengths of the μ Centauri lines given in the table were reduced, by means of Hartmann's formula, from measures made on Pickering's reproduction, the fiducial lines used being 4121·0 (He), $H_\gamma$, and $H_\beta$.

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# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

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Vol. LXV. No. 1. November 1904.

## ANNOUNCEMENT OF PAPERS RECEIVED.

Post-cards, giving the titles of such Papers as have been received or promised up to the Tuesday preceding the day of the Ordinary Meeting, will be sent to such Fellows who inform the Assistant Secretary of their wish to receive them.

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## MEMOIRS.

Fellows are informed that in future a separate application for each volume of the *Memoirs* will not be required. Fellows sending their names to the Assistant Secretary will receive the volumes to which they are entitled, as they are issued, without further application.

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